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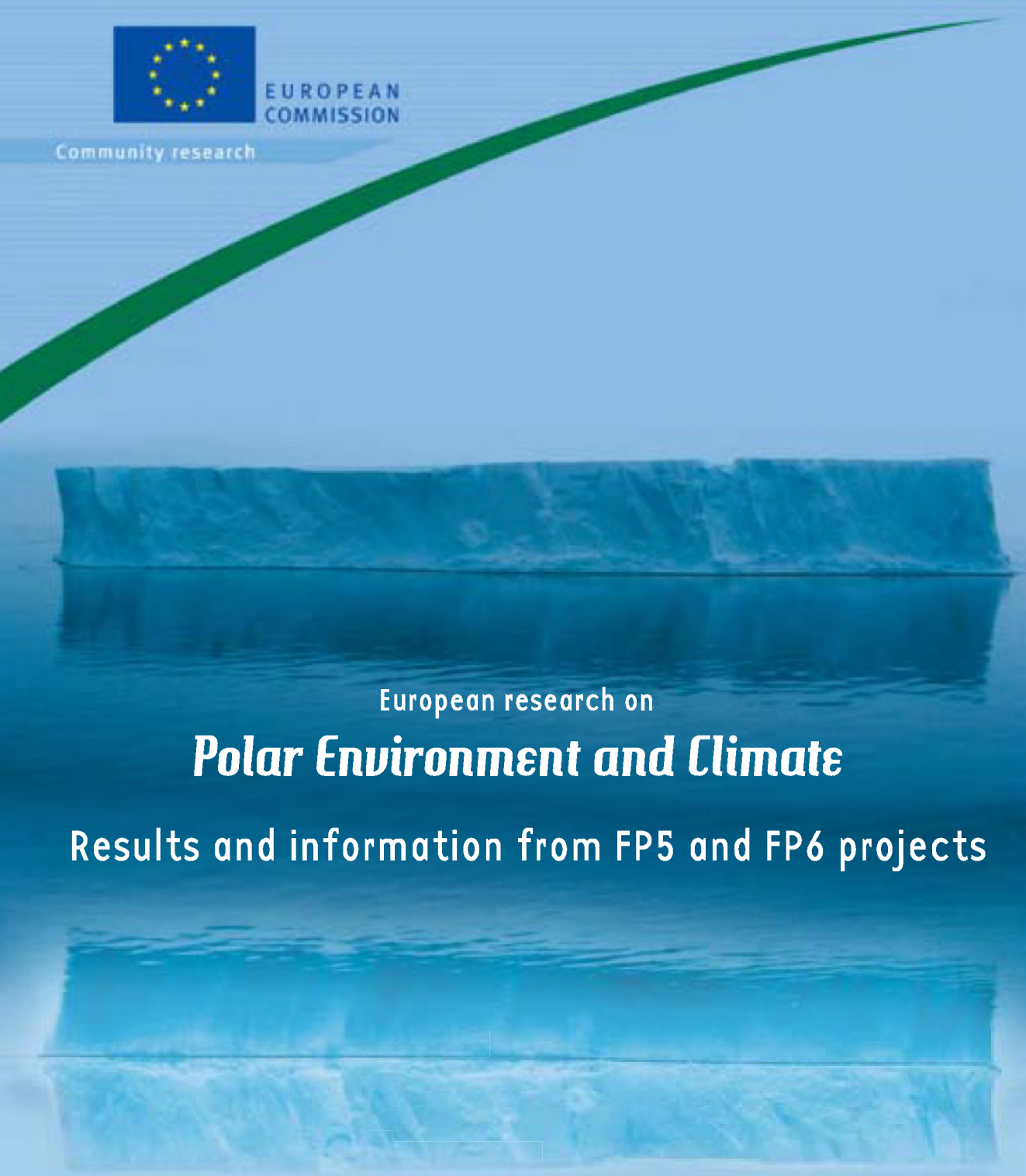

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Polar Environment and Climate

Results and information from FP5 and FP6 projects

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European research on

Polar Environment and Climate

Results and information from FP5 and FP6 projects

edited by

B.V. Vangelsten, D. Cardinal and R. Casale

Climate Change and Environmental Risks Unit,
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Preface

Both distant and near, neglected yet essential, the Polar Regions include vast deserts and populated areas. Although they may appear immutable, these highly dynamic environments play a fundamental role in the health and climate of our planet. For example, Antarctica accounts for 90% of the world's ice and acts as a formidable buffer protecting us from rapid warming. Polar ice caps also constitute archives of world climatic variations, used both for the reconstruction of past climate and for the validation of models predicting future climate changes. With global warming these regions are now facing major challenges like the disappearance of summer pack ice in the Arctic at the end of this century.

This publication is a European Commission contribution to the International Polar Year 2007-2008 and its release is planned to coincide with the international symposium ***"Polar Environment and Climate: The Challenges - European Research in the context of the International Polar Year"*** organised by the European Commission-Directorate General for Research on the 5-6 March 2007 in Brussels. Since the first International Polar Year in 1882-83 there have been a number of major international polar interdisciplinary science initiatives which considerably influenced our understanding of global processes. The last International Geophysical Year in 1957-58 focussed on polar research, involved 80,000 scientists from 67 countries and produced unprecedented exploration and discoveries that fundamentally changed how science was conducted in the Polar Regions. Fifty years on, the International Polar Year in 2007-2008 offers enormous opportunities for a further quantum step upwards in our understanding of polar systems.

The European Commission supports research in the Polar Regions through its Framework Programme. Under the European Union's 5th and 6th Framework Programmes for Research (FP5 and FP6) more than 50 projects related partly or entirely to polar issues were financed with a total funding of approximately 200 million Euros. They are focussed on climate change and the functioning of the Earth system, environment and health, natural hazards, natural resources, research infrastructures and coordination activities.

This catalogue provides detailed information and achievements of these projects supported within FP5 and FP6. Specifically, the information provides a description of projects, their objectives and their final scientific achievements for finished projects. I am convinced this information, summarizing what has already been done and what is ongoing will be useful to the research community and to policy makers in Europe and elsewhere. In particular, by going through the catalogue, the reader will undoubtedly be impressed by the diversity of actions characterised by scientific achievements and the key information with high impacts for Europeans. This catalogue will also help to identify research needs in fields relevant to polar environment and climate in the 7th Framework Programme.

Janez Potočnik,
European Commissioner for Science and Research

Acknowledgements

Special acknowledgements are due to Mrs Conchita Menendez for her contribution to the editing and publication of this catalogue

Table of Contents

1. Climate System 7

6th Framework Programme 9

CARBOOCEAN - Marine carbon sources and sinks assessment 11
CARBO-NORTH - Quantifying the Carbon budget in Northern Russia: past, present and future 13
DAMOCLES - Developing Arctic Modelling and Observing Capabilities for Long-term Environmental Studies 15
DYNAMITE- Understanding of the dynamics of the coupled climate system 17
ENSEMBLES - ENSEMBLE based Predictions of Climate Changes and their Impacts 19
EPICA-MIS - New Palaeoreconstructions from Antarctic Ice and Marine Records 22
IPY-CARE - Climate of the Arctic and its Role for Europe (CARE) – a European component of the International Polar Year 24
MILLENNIUM - European climate of the last millennium 26
SCOUT-O3 - Stratosphere-Climate Links with Emphasis on the UTLS 28
SEARCH for DAMOCLES - Study of Environmental Arctic Change - Developing Arctic Modelling and Observing Capability for Long-term Environment Studies 30

5th Framework Programme 33

6C - Carbonate Chemistry, Carbon Cycle and Climate Change (a multidisciplinary view) 35
AICSEX - Arctic Ice Cover Simulation Experiment 37
ASOF-N - Arctic-Subarctic Ocean Flux Array for European Climate: North 41
ASOF-W - Arctic-Subarctic Ocean Flux-Array for European Climate: West 44
BALANCE -Global Change Vulnerabilities in the Barents Region: Linking Arctic Natural Resources, Climate Change and Economies 48
CANDIDOZ - Chemical and dynamical influences on decadal ozone changes 51
CONVECTION - Greenland sea convection mechanisms and their climatic implications 53
CRYOSTAT - CRYOspheric STudies of Atmospheric Trends in stratospherically and radiatively important gases 56
ENVISNOW - Development of Generic Earth Observation Based Snow Parameter Retrieval Algorithms 60
EPICA - The European Project for Ice Coring in Antarctica 62
EUPLEX - European Polar Stratospheric Cloud and Lee Wave Experiment 66
EuroSOLVE - Improved understanding of stratospheric ozone loss by collaboration with the SAGE III Ozone Loss and Validation Experiment 69
GLIMPSE - Global implications of Arctic climate processes and feedbacks 72
GreenICE - Greenland arctic shelf Ice and Climate Experiment 76
MAIA - Monitoring the Atlantic inflow towards the Arctic 78
MAPSCORE - Mapping of polar stratospheric clouds and ozone levels relevant to the region of Europe 80
Meth-MonitEUr - Methane Monitoring in the European Region 83
MOEN - Meridional Overturning Exchange with Nordic Seas 85
NOCES - Northern ocean-atmosphere carbon exchange study 87
POP - Pole Ocean Pole project 90
QUOBI - Quantitative Understanding of Ozone losses by Bipolar Investigations 93
RAMAS - Radiometer for Atmospheric Measurements At Summit 95
SAMMOA - Spring-to-Autumn measurements and modelling of ozone and active species 98
SCANNET - Scandinavian/North European Network of Terrestrial Field Bases 102
SIBERIA II – Multi-Sensor Concepts for Greenhouse Gas Accounting of Northern Eurasia 105
SITHOS - Sea Ice Thickness Observation System 108
SPICE - Space borne measurements of Arctic Glaciers and implications for Sea Level 112
TCOS-Siberia – Terrestrial Carbon Observing System – Siberia 116
TOPOZ III - Towards the Prediction of Stratospheric Ozone III: The Partitioning of the NOy Components 121
TRACTOR - Tracer and Circulation in The Nordic Seas Region 123

2. Environment and Health 127

ANEMONE - Assessment of neurobehavioural endpoints and markers of neurotoxicant exposures 129
BEEP - Biological effects of environmental pollution in marine coastal ecosystems 132
BIOCET - Bioaccumulation of persistent organic pollutants in small cetaceans in European waters: transport pathways and impact on reproduction 135
COMPARE - Comparison of exposure-effect pathways to improve the assessment of human health risks of complex environmental mixtures of organohalogen 138

EDEN –Emerging Diseases in a changing European Environment 143
FAMIZ - Food web uptake of persistent organic pollutants in the arctic marginal ice zone of the Barents Sea 146
FIRE - Risk assessment of brominated flame-retardants as suspected endocrine disrupters for human and wildlife health 148
INUENDO - Biopersistent organochlorines in diet and human fertility. epidemiologic studies of time to pregnancy and semen quality in inuit and european populations 151

3. Natural Hazards 153

GLACIORISK - Survey and prevention of extreme glaciological hazards in European mountainous regions 155

4. Natural Resources 157

EUR-OCEANS - EURopean network of excellence for OCean Ecosystems ANalysis 159
HERMES - Hotspot Ecosystem Research on the Margins of European Seas 162
IRIS - Ice ridging information for decision making in shipping operations 164

5. Research Infrastructures 167

ALOMAR eaRI – Arctic Lidar Observatory for Middle Atmospheric Research 169
ARCFAC V – The European Centre for Arctic Environmental Research 171
ATANS – Enhanced Transnational Access to Abisko Scientific Research Station 172
EISCAT_3D – European Next Generation Incoherent Scatter Radar 173
EISCAT_USERS_1 – Access to EISCAT facilities for new users 174

6. ERA-NET 175

EUROPOLAR - The European Polar Consortium: Strategic Coordination and Networking of European Polar RTD Programmes 177

1. Climate System

6th Framework Programme

CARBOOCEAN - Marine carbon sources and sinks assessment

GOCE-511176

http://www.carboocean.org/

Instrument:	FP6 Integrated Project (IP)	Contract starting date: 01/01/2005
Total project cost:	19.271.618 €	Duration: 60 months
EC Contribution:	14.449.600 €	
Organization:	Bjerknes Centre for Climate Research, University of Bergen, Norway	
Co-ordinator:	Christoph Heinze (christoph.heinze@gfi.uib.no)	
EC Contact person:	Claus Bruening (claus.bruening@ec.europa.eu)	

Abstract

Changes in the Earth's climate are the result of both internal variability within the climate system and external factors, such as anthropogenic emissions of long-lived greenhouse gases. Carbon dioxid (CO_2) is the most important manageable driving agent for climate change. Greenhouse gases, such as CO_2, have a lasting effect on our Earth since they tend to warm up the atmosphere. Since 1750, the atmospheric CO_2 concentration has been rising steadily. Most of the observed warming over the last 50 years is attributed to the increase in greenhouse gas concentration. CO_2 cycles among the atmosphere, the land, and the oceans. On a long term, around 50% of the anthropogenic CO_2 emissions are being taken up by the oceans and the land. Since the ocean has the most significant overall potential as a sink for anthropogenic CO_2, the correct quantification of this sink is a fundamental necessary condition for all realistic prognostic climate simulations.

It is the main task of the CARBOOCEAN Consortium to determine the ocean's quantitative role for uptake of CO_2. This new scientific knowledge is essential to a quantitative risk/uncertainty judgment on the expected consequences of rising atmospheric CO_2 concentrations. Based on this judgment, it will be possible to guide the development of appropriate mitigation actions, such as the management of CO_2 emission reductions within a global context (e.g., Kyoto Protocol, 1997).

The CARBOOCEAN Consortium consists of 45 international groups that have started an integrated research activity on the marine carbon cycle by 1 January 2005. The participating countries are Belgium, Denmark, France, Germany, Iceland, Morocco, the Netherlands, Norway, Poland, Spain, Sweden, Switzerland, United Kingdom and the USA.

Partners

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2	ULB, Université Libre de Bruxelles	Belgium
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12b	MPIMET Max-Planck-Institut für Meteorologie	Germany
13	TUHH, Technical University Hamburg-Harburg	Germany
14	University of Bremen	Germany
14a	IUPHB, University of Bremen, Institut für Umweltphysik	Germany
14b	Uni-HB, University of Bremen, Geosciences	Germany
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18	Centre Nationale de la Récherche Scientifique	France
18a	CNRS.LOV, Laboratoire d`Océanographie de Villefranche	France
18b	CNRS/LEGOS, Laboratoire d'Etudes en Geopysique et Océanographie Spatiales	France
19	UP, University of Perpignan	France
20	MRI-IS, Marine Research Institute	Iceland
21	INRH, Institut National de Recherche Halieutique, Casablanca	Morocco
22	Rijksuniversiteit Groningen	Netherlands
22a	RUG, Rijksuniversiteit Groningen	Netherlands
22b	CIO, Centrum voor Isotopen Onderzoek, University Groningen	Netherlands
23	NIOO, Netherlands Institute of Ecology	Netherlands
24	NERSC, Nansen Environmental and Remote Sensing Center	Norway
25	NILU, Norwegian Institute of Air Research	Norway
26	IO PAS, Institute of Oceanology of the Polish Academy of Sciences	Poland
27	UGOT, University of Göteborg	Sweden
28	MetO (UK) Hadley Centre for Climate Prediction and Research	UK
29	NERC-SOC, Southampton Oceanography Centre	UK
30	UESSEX, University of Essex	UK
31	FastOpt	Germany
32	IOC, Intergovernmental Oceanographic Commission of UNESCO	France
33	NILU Polska Ltd.	Poland
34	SAUG, Philippe Saugier ingenieur-conseil	France
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36	GCCA of NOAA/PMEL, Ocean Climate Research Divison/Pacific Environmental Laboratory, Seattle	USA
37	Penn State, The Pennsylvania State University	USA
38	Princeton/AOSP, Princeton University, Atmospheric and Oceanic Sciences Program	USA
39	S.I.O., Scripps Institution of Oceanography at University of California San Diego	USA
40	TAMU-RF, Texas A&M Research Foundation	USA
41	CMS, College of Marine Studies, University of Delaware	USA
42	ETH Zurich	Switzerland

43	University of Hawaii at Manoa	USA
44	Dalhousi University	Canada
45	Carbon Dioxide Information Analysis Center	USA

CARBO-NORTH - Quantifying the Carbon budget in Northern Russia: past, present and future

036993

http://www.carbo.org/

Instrument:	FP6 Project (STREP)	Contract starting date: 01/11/2006
Total project cost:	3.622.074 €	Duration: 42 months
EC Contribution:	3.099.822 €	
Organization:	Stockholms Universitet	Stockholm, Sweden
Co-ordinator:	Peter Kuhry (peter.kuhry@natgeo.su.se)	
EC Contact person:	Anastasios Kentarchos (anastasios.kentarchos@ec.europa.eu)	

Abstract

"CARBO-North aims at quantifying the carbon budget in Northern Russia across temporal and spatial scales. Activities address rates of ecosystem change, effects on the carbon budget (radiative forcing), and global climate and policy implications (Kyoto). Recent research on the impacts of climate change in high latitude regions has mostly assessed the equilibrium response of ecosystems, for instance what is the potential location of the arctic treeline or the southern limit of permafrost under conditions of global warming. However, transient responses are of much greater importance from a policy perspective.

- How quickly will the arctic treeline migrate?
- How quickly will permafrost thaw?
- How quickly will enhanced soil organic matter decay result in increased greenhouse gas emissions and leaching?

Different time lags in these processes will cause significant deviations from equilibrium response. Proposed field study areas in Northeast European Russia are characterized by gradual lowland transitions in vegetation and permafrost conditions. Dedicated climate models will provide requested variables and time slices as input to ecosystem studies. Analyses will be conducted to assess the sensitivity of climate model output to a suite of land cover, ground and permafrost schemes. Proxydata will be used to evaluate rates of ecosystem change under past climatic changes. The present environment will be studied from the plot to landscape scales with a variety of approaches, including assessments of human-induced and natural disturbances. Detailed monitoring and mapping of vegetation, soil and permafrost will provide input for process-oriented studies (treeline patch dynamics; tundra/forest/river carbon fluxes; ground subsidence, etc) and GIS-based upscaling to regional levels. Results are used for integrated ecosystem modelling, calculation of net radiative effects and assessment of the sensitivity of climate model predictions to transient environmental changes."

Partners

N°	Organisation	Country
1	Stockholms Universitet	Sweden
2	Lunds Universitet	Sweden
3	Alfred-Wegener-Institut für Polar-und Meeresforschung	Germany
4	Ernst-Moritz-Arndt-University of Greifswald	Germany
5	Danmarks Meteorologiske Institut.	Denmark
6	Kobenhavns Universitet	Denmark

7	Institute of Biology of Komi Scientific Center of the Rural Branch of the Russian Academy of Sciences	Russia
8	Met Office	UK
9	University College London.	UK
10	The University of NOttingham	UK
11	Helsingin Yliopisto	Finland
12	Kuopion Yliopisto	Finland
13	Universiteit Utrecht	Netherlands
14	Wageningen Universiteit	Netherlands
15	ENSIS Ltd	UK
16	CHERMET	Russia

DAMOCLES - Developing Arctic Modelling and Observing Capabilities for Long-term Environmental Studies

018509

http://www.damocles-eu.org/

Instrument:	FP6 Integrated Project (IP)	Contract starting date: 01/12/2005
Total project cost:	24.670.000 € + 422.914 € (TTC)	Duration: 48 months
EC Contribution:	16.100.000 € + 422.914 € (TTC)	
Organisation:	Université Pierre et Marie Curie	Paris, France
Co-ordinator:	Jean-Claude Gascard (gascard@lodyc.jussieu.fr)	
EC Contact person:	Riccardo Casale (riccardo.casale@ec.europa.eu.)	
	Damien Cardinal (damien.cardinal@ec.europa.eu)	

Abstract

All state-of-the-art climate models predict that the perennial sea-ice of the Arctic Ocean will disappear within a few decades or less. Important questions remain as to whether this expectation is justified, and if so when this change will take place and what effect it will have on climate on a regional-to-global scale. Such a dramatic physical affront to the ocean-atmosphere-cryosphere system in northern latitudes which corresponds to a change in surface albedo from more than 0.8 to less than 0.3 over a surface larger than Europe, is bound to have radical effects on human activities with immediate impacts on the indigenous inhabitants of the circum-Arctic region and the ecosystem on which they depend, and widespread effects on socio-economic activity on hemispheric scale. We propose an Integrated Project for Developing Arctic Modelling and Observing Capabilities for Long-term Environmental Studies (DAMOCLES) with the following objectives: (1) identify and understand the changes occurring in the Sea-Ice, Atmosphere and Ocean of the Arctic and Sub arctic domain, (2) improve the realism by which these changes are simulated in models, thus extending the lead-time prior to the onset of extreme climate events, (3) determine appropriate adaptation strategies for a range of anticipated socio-economic impacts following the disappearance of the perennial Sea-Ice. At a time when the International Polar Year (IPY) will focus on the science of the polar regions and on the human dimension of polar change, DAMOCLES will provide a contribution to reflect both the skills of European Sciences and the importance to European interests. DAMOCLES represents the integrated efforts of 45 (Original) + 4 (TTC extension) European research institutions including 10 SMEs distributed among 12 European countries, and coordinated with the USA, Russia, Canada and Japan.

Partners

N°	Organisation	Country
1	Université Pierre et Marie Curie	France
2	Alfred Wegener Institute for Polar and Marine Research	Germany
3	Swedish Meteorological and Hydrological Institute	Sweden
4	Nansen Environmental and Remote Sensing Center	Norway
5	Finnish Institute of Marine Research	Finland
6	Meteorologisk Institut	Norway
7	Norwegian Polar Institute	Norway
8	Arctic Centre university of Lapland	Finland
9	Goteborg University	Sweden

10	Institute of Marine Research	Norway
11	Centre for Environment, Fisheries and Aquaculture Science	UK
12	Danish meteorological Institute	Denmark
13	University of Cambridge	UK
14	University of Bremen	Germany
15	University College London	UK
16	Stockholm University	Sweden
17	University of Bergen	Norway
18	Foundation for Research and Technology - Hellas	Greece
19	University of Hamburg	Germany
20	Instytut Oceanologii, Polska Akademia nauk	Poland
21	OPTIMARE Sensorsysteme AG	Germany
22	Finnish Meteorological Institute	Finland
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25	Centre National de la Recherche Scientifique	France
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47	Institute of Numerical Mathematics, Russian Academy of Sciences, Moscow	Russia
48	Nansen International Environmental and Remote Sensing Center, Saint Petersburg	Russia
49	Research Centre for Earth Operative Monitoring, Moscow	Russia

DYNAMITE- Understanding of the dynamics of the coupled climate system

003903

http://dynamite.nersc.no/

Instrument:	FP6 Project (STREP)	Contract starting date: 01/03/2005
Total project cost:	3.122.214 €	Duration: 36 months
EC Contribution:	1.998.000 €	
Organization:	Nansen Environment and Remote Sensing Center, Bergen, Norway	
Co-ordinator:	Helge Drange (helge.drange@nersc.no)	
EC Contact person:	Georgios Amanatidis (georgios.amanatidis@ec.europa.eu)	

Abstract

Deeper understanding of the intrinsic variability and stability properties of the main climate variability modes is needed to assess confidence in the detection, attribution and prediction of global and regional climate change, to improve seasonal predictions, and to understand the shortcomings of current prediction systems. DYNAMITE will explore the fundamental dynamical mechanisms of two of the most important modes of climate variability: the North Atlantic Oscillation/Arctic Oscillation (NAO/AO) and the El Niño-Southern Oscillation (ENSO). The project will elucidate key theoretical and practical aspects of the NAO/AO and ENSO through analyses of available observations, application of classical and new theory, and use of idealised and state-of-the-art numerical models of the atmosphere, ocean, land-surface, sea-ice, marine biology, and the coupled climate system. Specifically, DYNAMITE will advance the understanding of strongly and weakly coupled processes underlying the natural variability of ENSO and NAO/AO; it will evaluate the representation of the coupled processes underlying ENSO and the NAO in state-of-the-art models used to predict climate change; it will advance understanding of the response of ENSO and NAO/AO to climate change; and it will assess the role of ocean biology in the variability of the tropical coupled climate system, including ENSO. DYNAMITE will be implemented by a partnership of world class climate research institutions, including a candidate country and several SMEs. All of the results and findings gained in DYNAMITE will be transferred to the climate modelling community both in and outside Europe by bi-annual electronic newsletters and a dedicated and open DYNAMITE model workshop at the end of the project. DYNAMITE will improve the European capability to make predictions of the state of the climate system from seasons to centuries ahead, thereby contributing to the competitiveness and sustainability of the European Union.

Partners

N°	Organisation	Country
1	Nansen Environment and Remote Sensing Center	Norway
2	University of Reading	UK
3	Centre Européen de Recherche et de Formation Avancée en Calcul Scientifique	France
4	Met Office	UK
5	Centre National de la Recherche Scientifique	France
6	Chinese Academy of Sciences – Institute of Atmospheric Physics	China
7	Leibniz Institut für Meereswissenschaften	Germany

8	Istituto Nazionale di Geofisica e Vulcanologia	Italy
9	Administratia Nationala de Meteorologie	Romania
10	Vestas Ásia Pacific A/S	Denmark
11	Bergenshalvoeens Kommunale Kraftselskap Raadgiving AS	Norway
12	Societa Generale di Ingegneria - S.G.I. SPA Di Rubano	Italy
13	VEXCEL UK Limited	UK

ENSEMBLES - ENSEMBLE based Predictions of Climate Changes and their Impacts

GOCE-CT-2003-505539

http://www.ensembles-eu.org

Instrument:	FP6 Integrated Project (IP)	Contract starting date: 01/09/2004
Total project cost:	22.856.350 €	Duration: 60 months
EC Contribution:	15.000.000 €	
Organization:	Met Office	Exeter, UK
Co-ordinator:	David Griggs (david.griggs@metoffice.com)	
EC Contact person:	Georgios Amanatidis (georgios.amanatidis@ec.europa.eu)	

Abstract

Prediction of both natural climate variability and human impact on climate is inherently probabilistic, due to uncertainties in forecast initial conditions, representation of key processes within models, and climatic forcing factors. Hence, reliable estimates of climatic risk can only be made through ensemble integrations of Earth - System Models in which these uncertainties are explicitly incorporated. For the first time ever, a common ensemble forecast system will be developed for use across a range of timescales (seasonal, decadal, and longer) and spatial scales (global, regional, and local). This model system will be used to construct integrated scenarios of future climate change, including both non-intervention and stabilisation scenarios. This will provide a basis for quantitative risk assessment of climate change and climate variability, with emphasis on changes in extremes, including changes in storminess and precipitation, and the severity and frequency of drought, and the effects of "surprises", such as the shutdown of the thermohaline circulation. Most importantly, the model system will be extensively validated. Hind casts made by the model system for the 20th century will be compared against quality-controlled, high-resolution gridded datasets for Europe. Probability forecasts made with the model system on the seasonal and decadal timescales will also be validated against existing data. The exploitation of the results will be maximised by linking the outputs of the ensemble prediction system to a wide range of applications. In turn, feedbacks from these impact areas back to the climate system will also be addressed. Thus ENSEMBLES will have a structuring effect on European research by bringing together an unprecedented spectrum of world-leading expertise. This expertise will be mobilised to maintain and extend European pre-eminence in the provision of policy-relevant information on climate and climate change and its interactions with society.

Partners

N°	Organisation	Country
1	Met Office	UK
2	Meteo France, Centre National de Recherches Météorologiques	France
3	Centre National de la Recherche Scientifique	France
4	Danmarks Meteorologiske Institut	Denmark
5	European Centre for Medium-Range Weather Forecasts	UK
6	International Institute for Applied Systems Analysis	Austria
7	Istituto Nazionale di Geofisica e Vulcanologia	Italy
8	Koninklijk Nederlands Meteorologisch Instituut	Netherlands

9	University of Bristol	UK
10	Max Planck Gesellschaft zur Foerderung der Wissenschaften e.v.	Germany
11	National Observatory of Athens	Greece
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30	Electricite de France	France
31	Ecole Normale Superieure	France
32	Eidgenoessische Technische Hochschule Zuerich	Switzerland
34	Fondazione ENI Enrico Mattei	Italy
35	Fundación para la Investigación del Clima	Spain
36	Ilmatieteen Laitos	Finland
37	Fachhochschule fuer Technik Stuttgart	Germany
38	Freie Universitaet Berlin	Germany
40	GKSS Forschungszentrum Geesthacht GmbH	Germany
41	Ustav Fyziky Atmosfery AV CR	Czech Rep.
42	The Abdus Salam International Centre for Theoretical Physics	Italy
43	Institut fuer Meereskunde an der Universitaet	Germany
44	Instituto Nacional de Meteorologia	Spain
45	The Trustees of Columbia University in New York City	USA
46	Institut Universitaire Kurt Boesch	Switzerland
47	Universität Stuttgart	Germany
48	Commission of the European Communities - Directorate General Joint Research Centre	Belgium
49	London School of Economics and Political Science	UK
50	London School of Hygiene and Tropical Medicine	UK
51	Meteorologisk Institutt	Norway
52	Meteoschweiz	Switzerland
54	Nansen Environmental and Remote Sensing Center	Norway
55	Institutul National de Hidrologie si Gospodarire a Apelor Bucuresti	Romania
56	Administratia Nationala de Meteorologie	Romania
57	Research Centre for Agricultural and, Forest - Environment Polish Academy of Sciences	Poland
58	Potsdam-Institut für Klimafolgenforschung e.v.	Germany
59	Rijksinstituut voor Volksgezondheid en Milieu	Netherlands
60	Societe de Mathematiques Appliquees et de Sciences Humaines	France
61	Suomen Ymparistokeskus	Finland

62	Universidad de Cantabria	Spain
63	Universite Catholique de Louvain	Belgium
64	Universidad de Castilla la Mancha	Spain
65	Universitetet i Oslo	Norway
67	Lunds Universitet	Sweden
68	Universität Kassel	Germany
69	University of Liverpool	UK
70	University of Oxford	UK
73	Université Joseph Fourier, Grenoble	France
74	Met Eireann	Ireland

EPICA-MIS - New Palaeoreconstructions from Antarctic Ice and Marine Records

003868

http://www-lgge.ujf-grenoble.fr/epica-mis/

Instrument:	FP6 Project (STREP)	Contract start date: 01/12/2004
Project total cost:	5.470.257 €	Duration: 36 months
EC contribution:	2.500.000 €	
Organisation:	Centre National de la Recherche Scientifique, Grenoble, France	
Co-ordinator:	Dominique Raynaud (raynaud@lgge.obs.ujf-grenoble.fr)	
EC Contact person:	Riccardo Casale (riccardo.casale@ec.europa.eu)	
	Damien Cardinal (damien.cardinal@ec.europa.eu)	

Abstract

The objective of the Specific Targeted Research Project EPICA-MIS is to produce palaeoreconstructions and integrated climate analysis through marine and ice core studies. It will contribute to the development of novel palaeoreconstruction methods by providing unique palaeorecords and developing new proxies of critical properties of the climate system. The two Antarctic deep ice cores will be completed and they will for the first time reveal atmospheric records of greenhouse gases like CO_2 and methane reaching 800,000 years back in time. Novel multi-parameter and high-resolution records of climate-relevant parameters like ice isotopes, greenhouse gases, dust and soluble impurities will be produced from the new Antarctic ice cores. They will be compared and correlated with palaeoreconstructions from marine, Greenland and other Antarctic regions. A key task here is to produce common timescales for the records by comparing the individual datings and by investigating novel tephra and palaeomagnetic correlation methods. The produced multiproxy reconstructions will provide an outstanding platform for understanding and modelling the past and present climate. Because the reconstructions from both ocean and ice cores will be integrated and will use novel indicators for instance for sea ice, Antarctic insolation, iron or opal isotopes, climatic issues like the carbon cycle, sea surface temperature, and the climatic coupling between the northern and southern hemispheres can be addressed with new perspectives. As strategies for mitigation and adaptation to global change have to be based on predictions on future climate, the EPICA-MIS novel palaeoreconstructions will produce new evidence about climate dynamics and variability necessary to improve and test policy-relevant models. The Research Project goes a step further in integrating the European ice core research groups with marine palaeoclimate research groups, thus forming a strong European Research Area.

Partners

N°	Organisation	Country
1	Centre National de la Recherche Scientifique	France
2	Alfred-Wegener-Institut für Polar- und Meeresforschung	Germany
4	Consorzio Nazionale Interuniversitario per le Scienze del Mare	Italy
5	Université Libre de Bruxelles	Belgium
6	Koebenhavns Universitet	Denmark
7	Institut Polaire Français - Paul Emile Victor	France
8	Utrecht University	Netherlands
9	Stockholms universitet	Sweden

10	Norwegian Polar Institute	Norway
11	University of Bern	Switzerland
12	Natural Environment Research Council	UK
13	The Chancellor, Masters and Scholars of the University of Cambridge	UK
14	Commissariat à l'Energie Atomique	France
15	Consorzio per l'attuazione del Programma Nazionale di Ricerche in Antartide	Italy

IPY-CARE - Climate of the Arctic and its Role for Europe (CARE) – a European component of the International Polar Year

010292

http://www.ipy-care.org/

Instrument:	FP6 Specific Support Action (SSA)	Contract starting date: 01/07/2005
Total project cost:	409.000 €	Duration: 18 months
EC Contribution:	395.000 €	
Organisation:	Nansen Environmental and Remote Sensing Center, Bergen, Norway	
Co-ordinator:	Ola M. Johannessen (ola.johannessen@nersc.no)	
EC Contact person:	Riccardo Casale (riccardo.casale@ec.europa.eu)	
	Damien Cardinal (damien.cardinal@ec.europa.eu)	

Abstract

The overall objective of IPY-CARE is to create, co-ordinate and prepare a Pan-European science and implementation plan for Arctic climate change and ecosystems research programme as contribution to the International Polar Year.

The Arctic has over the last 2-3 decades warmed more than other regions of the world, and the sea ice cover has decreased in the order of 10% in the same period. Climate models furthermore indicate that anthropogenic global warming will be enhanced in the northern high latitudes due to complex feedback mechanisms in the atmosphere–ocean–ice system. At the end of this century, the Arctic Ocean is predicted to be "a blue ocean" during summer time. The Arctic may therefore encounter the most rapid and dramatic changes during the 21st century, with significant consequences for environment and human activities.

The IPY-CARE Specific Support Action will create a coordinated plan for European Arctic climate and ecosystem research programme by organising expert groups who will develop a science and implementation plan for a coordinated pan-European IPY-CARE programme. Expert groups will be established for the following six modules which represent the main components of the programme: M1: Processes determining Arctic climate variability and changes; M2: Marine biological processes in response to climate change; M3: Air-sea-ice meso-scale processes and climate variability; M4: Past climate variability; M5: Remote sensing and new technology for climate data provision, and M6: Assessment of Arctic climate change impacts on climate in Europe including the Mediterranean area and socio-economic consequences for Europe. An important part of the expert groups' activities will be to organize an Arctic climate symposium open for all.

IPY-CARE will require large and multi-disciplinary resources that can only be mobilized by a joint effort of a broad consortium, which includes all the major polar research institutions and groups in Europe. IPY-CARE will build up promotion and outreach activities to rise the awareness of the importance of the Arctic for global climate, resource exploitation, transport and environmental vulnerability. Furthermore, IPY-CARE will develop education and training programmes in the area of Arctic climate research for young scientists in Europe.

Partners

N°	Organisation	Country
1	Nansen Environmental and Remote Sensing Center	Norway
2	Alfred Wegener Institute for Polar Research	Germany
3	Max Planck Institute for Meteorology	Germany
4	The Norwegian Polar Institute	Norway
5	Academy of Sciences Mainz/Institute for Polar Ecology & GEOMAR Center for Marine Geosiences	Germany
6	University of Bergen, The Bjerknes Centre for Climate Research	Norway
7	Pierre et Marie Curie University (LODYC)	France
8	Finnish Institute of Marine Research	Finland
9	Göteborg University (UGOT), Deparment of Chemistry	Sweden
10	Scottish Association for Marine Science	UK
11	Danish Meteorological Institute	Denmark
12	State Research Center Arctic and Antarctic Research Institute	Russia
13	Nansen International Environmental and Remote Sensing Center	Russia
14	Centre National de la Recherche Scientifique	France
15	Foundation for Research and Technology	Greece
16	National Meteorological Administration	Romania
17	Institute de Ciencia i Tecnologia Ambientals	Spain
18	Institute of Oceanology, Polish Academy of Sciences	Poland
19	International Polar Foundation	Belgium

MILLENNIUM - European climate of the last millennium

017008

http://www.millenniumproject.net/

Instrument:	FP6 Integrated Project (IP)	Contract starting date: 01/01/2006
Total project cost:	15.513.096 €	Duration: 48 months
EC Contribution:	12.600.000 €	
Organization:	University of Wales Swansea	Swansea, UK
Co-ordinator:	Danny McCarroll (D.McCarroll@swansea.ac.uk)	
EC Contact person:	Riccardo Casale (riccardo.casale@ec.europa.eu)	
	Damien Cardinal (damien.cardinal@ec.europa.eu)	

Abstract

Millennium will answer one of the most critical questions in climate research: does the magnitude and rate of 20th Century climate change exceed the natural variability of European climate over the last millennium? Existing climate reconstructions rely on inadequate data and underestimate variability. Improved GCM parameterization requires more accurate reconstructions and integrated modelling. We will supply high-resolution chronologies that capture the magnitude and rate of change and the magnitude and frequency of extreme events over the last 1000 years. Our multi-disciplinary team will use innovative and developing technologies to extract quantitative palaeoclimate information from documentary and natural archives, including trees, lakes, mires and ice cores. A multi-proxy approach provides seasonal palaeoclimate signals with quantified precision. Advances in dating allow us, for the first time, to place terrestrial and marine proxy records on the same timescale, allowing lead and lag relationships in ocean-atmosphere forcing to be captured. Annually banded seashells will be cross-dated like tree rings, and tephra-rich sediments used to construct a marine chronology independent of P14PC dating. This can be used to reconstruct changes in ventilation linked directly to the strength of North Atlantic circulation. Millennial reconstructions of European climate, at a range of scales, will define whether recent climate change is unusual in the context of past variability. Millennium proxy-based reconstructions will be fused with a hierarchy of models, run over both millennium and century time scales using a purpose-built PC cluster and the huge resources of the Climateprediction.net distributed computing network. Integrated hind- and forecast modelling, (using HadCM3) will allow us to test whether current empirically reconstructed climate records based on regression methods underestimate climate sensitivity or if current GCM simulations give overestimates.

Partners

N°	Organisation	Country
1	University of Wales Swansea	UK
2	University of Oulu	Finland
3	Masaryk University of Brno	Czech Rep.
4	University Court of the University of St Andrews	UK
5	Swiss Federal Research Institute WSL	Switzerland
6	Scottish Association for Marine Science	UK
7	University of Tromsø	Norway
8	University of Oxford	UK
9	University of Bern	Switzerland

10	Paul Scherrer Institut	Switzerland
11	Slovenian Forestry Institute	Slovenia
12	DM Technology Limited	UK
13	Cox Analytical Systems Sweden AB	Sweden
14	Anglia Polytechnic University	UK
15	Helsingin yliopisto	Finland
16	UFZ - Umweltforschungszentrum Leipzig - Halle GmbH	Germany
17	Stockholms universitet	Sweden
18	University of Wales, Bangor	UK
19	Utrecht University	Netherlands
20	Forschungszentrum Juelich GmbH	Germany
21	Finnish Forest Research Institute	Finland
22	Norwegian Polar Institute	Norway
23	University of Aarhus	Denmark
24	Science Institute, University of Iceland	Iceland
25	NERC Isotope Geosciences Laboratory, British Geological Survey	UK
26	Umeå University	Sweden
27	Hohenheim University	Germany
28	Universitat de Barcelona	Spain
29	Adam Mickiewicz University	Poland
30	Institute of Geography Russian Academy of Sciences	Russia
31	Albert-Ludwigs-Universität Freiburg	Germany
32	The University of Edinburgh	UK
33	University of Sunderland	UK
34	Koninklijk Nederlands Meteorologisch Instituut	Netherlands
35	Institute of Meteorology and Water Management	Poland
36	University of Szeged	Hungary
37	Centre for Ecology and Hydrology	UK
38	University of Exeter	UK
39	Italian National Research Council	Italy

SCOUT-O3 - Stratosphere-Climate Links with Emphasis on the UTLS

GOCE-CT-2004-505390

http://www.ozone-sec.ch.cam.ac.uk/scout_o3/

Instrument:	FP6 Integrated Project (IP)	Contract starting date: 01/05/2004
Total project cost:	23.315.623 €	Duration: 60 months
EC Contribution:	15.000.000 €	
Organization:	University of Cambridge	Cambridge, UK
Co-ordinator:	John Pyle (john.pyle@atm.ch.cam.ac.uk	
EC Contact person:	Claus Bruening (claus.bruening@ec.europa.eu)	

Abstract

Reliable prediction of the future evolution of the ozone layer and surface UV is urgently required as a basis for informed decisions by European policy makers. The state of the ozone layer over the next decades will depend on the interplay between climate change and the impact and evolution of ozone depleting substances such as CFCs. The Montreal Protocol has successfully in reduced emissions and atmospheric concentrations of CFCs, which should return to their pre-ozone hole concentrations by about 2050. However, the ozone layer will most likely not return to its pre-ozone hole state and so the central question of the Montreal process - how and when will ozone and UV radiation recover as CFC concentrations fall? - remains. Indeed, in order to provide essential advice to policy makers, the answer to that question is required within the next years. In this ambitious integrated project, the European predictive capability will be strengthened by focusing effort on 6 main interlinked areas of research: coupled chemistry/climate models; the tropical UTLS; extratropical ozone and water vapour; UV radiation; global modelling; and fundamental chemical and microphysical processes. Strong scientific management, built on Europe's excellent previous experience in stratospheric science, will bring together a critical mass of European experts in laboratory studies, atmospheric measurements and modelling. It will exploit new satellite data, such as from ENVISAT, and new modelling approaches (e.g. fully-coupled chemistry-climate models; and the growing interaction with the numerical weather forecasting community), and take advantage of new and existing research facilities being developed at the national level. Valuable information for the assessment of the atmospheric impact of aviation will be obtained. This integrated project will thus provide essential information to European government and industry and will maintain Europe's leading position in stratospheric research.

Partners

N°	Organisation	Country
1	University of Cambridge	UK
2	Stiftung Alfred-Wegener-Institut für Polar- und Meeresforschung	Germany
3	Belgisch Instituut voor Ruimte Aeronomie	Belgium
4	Central Aerological Observatory	Russia
5	Centre National de la Recherche Scientifique	France
6	Chalmers Tekniska Hogskola AB	Sweden
7	Kemiai Kutatokozpont – Magyar Tudomanyos Akademia	Hungary
8	Consiglio Nazionale delle Ricerche	Italy
10	Cesky Hydrometeorologicky Ustav	Czech Rep.
11	Danmarks Meteorologiske Institut	Denmark

12	Psysikalisch-Meteorologisches Observatorium Davos und Welstrahlungszentrum	Switzerland
13	Democritus University of Thrace – Research Committee	Greece
14	Deutsches Zentrum für Luft und Raumfahrt e.V.	Germany
15	Deutscher Wetterdienst	Germany
16	Ente per le Nuove Tecnologie, l' Energia e l'Ambiente	Italy
17	Eidgenoessische Technische Hochschule	Switzerland
18	Ilmatieteen Laitos	Finland
19	Freie Universitaet Berlin.	Germany
20	Forschungszentrum Jülich GmbH	Germany
21	Forschungszentrum Karlsruhe GmbH	Germany
22	Imperial College of Science, Technology and Medicine.	UK
23	Instituto Nacional de Tecnica Aeroespacial	Spain
24	Istituto Nazionale di Geofisica e Vulcanologia	Italy
25	Istituto Nazionale di Ottica Applicata	Italy
26	Johannes Gutenberg Universitaet Mainz	Germany
27	Universitaet Graz	Austria
28	Max Planck Gesellschaft zur Foerderung der Wissenschaften e.V.	Germany
29	Meteo-France	France
30	National and Kapodistrian University of Athens.	Greece
31	Norsk Institutt for Luftforskning	Norway
32	Observatoire Cantonal de Neuchâtel	Switzerland
33	Paul Scherrer Institut	Switzerland
34	Rijksinstituut voor Volksgezondheid en Milieu	Netherlands
35	Koninklijk Nederlands Meteorologisch Instituut	Netherlands
36	Sveriges Meteorologiska Och Hydrologiska Institut	Sweden
37	Stratosphere - M, Ltd	Russia
38	Universitaet Bern	Switzerland
39	Universitaet Bremen	Germany
40	Universidad de Buenos Aires	Argentina
41	University of Crete	Greece
42	Johann Wolfgang Goethe Universitaet Frankfurt am Main	Germany
43	Goeteborgs Universitet.	Sweden
44	Universitaet Hannover.	Germany
45	Ruprecht-Karls-Universitaet Heidelberg.	Germany
46	Medizin Universitaet Innsbruck	Austria
47	Universitaet Karlsruhe (Technische Hochschule)	Germany
48	Lancaster University	UK
49	Università degli Studi de l'Aquila	Italy
50	University of Leeds.	UK
51	University of Leicester	UK
52	University of Manchester Institute of Science and Technology	UK
53	Universitetet I Oslo	Norway
54	Aristoteleio Panepistimio Thessalonikis	Greece
55	University of Wyoming	USA
56	The Regents of the University of California - UC Davis	USA
57	Met Office	UK
58	University of East Anglia	UK
59	Universitaet für Bodenkultur	Austria
60	Weather Informatics Ltd	UK

SEARCH for DAMOCLES - Study of Environmental Arctic Change - Developing Arctic Modelling and Observing Capability for Long-term Environment Studies

037111

http://www.damocles-eu.org

Instrument:	FP6 Specific Support Action (SSA)	Contract starting date: 01/10/2006
Total project cost:	605.000 €	Duration: 36 months
EC Contribution:	605.000 €	
Organization:	Université Pierre et Marie Curie	Paris, France
Co-ordinator:	Jean-Claude Gascard (gascard@lodyc.jussieu.fr)	
EC Contact person:	Riccardo Casale (riccardo.casale@ec.europa.eu)	
	Damien Cardinal (damien.cardinal@ec.europa.eu)	

Abstract

We are proposing a Specific Support Action "SEARCH for DAMOCLES" that is based on recent initiatives started in Europe and the USA in the field of Arctic marine ecosystems and Global change, with specific emphasis on Arctic Ocean long-term observatories. The SSA will capitalize on opportunities and significant benefits arising from coordination of large scale research programmes such as the European Integrated Project DAMOCLES (Developing Arctic Modelling and Observing Capabilities for Long-term Environmental studies) and the US research programme SEARCH (Study of Environmental ARctic Change). "SEARCH for DAMOCLES", positioned in the domain of Arctic Science, will be particularly timely in the context of the International Polar Year and will significantly contribute to the coordinated implementation of the DAMOCLES and SEARCH work programmes in the field of Global Change and Ecosystems. Close synchronization of these programmes will enhance the acquisition of pan-arctic data sets, and their analysis, the dissemination and archiving of results, as well as heightening public awareness. International workshops and conferences including other partners such as Canada, Russia, and Asian countries (Japan, China, and South Korea), will enable translation of the results into planning of integrated, future activities that will be based on the SSA "SEARCH for DAMOCLES". The coordination and synchronization of Arctic programmes such as DAMOCLES and SEARCH, through an SSA is a unique opportunity to ensure the necessary pan-arctic coverage of observations and data evaluation for understanding Arctic system variability, avoiding major gaps and unnecessary overlaps. This EU-US SSA will also contribute to promotion and facilitation of future RTD activities via prospective studies, exploratory measures and pilot actions. The EU-US SSA "SEARCH for DAMOCLES" is proposed for 3 years covering the 3 last years of the 4-year DAMOCLES Integrated Project (2006-2009) and the 2 years of the IPY (2007-2008).

Partners

N°	Organisation	Country
1	Université Pierre et Marie Curie	France
2	Columbia University	USA
3	Norwegian Meteorological Institute	Norway
4	University of Alaska Fairbanks	USA
5	Swedish Meteorological and Hydrological Institute	Sweden
6	Center for International and Environmental Research, Oslo	Norway

7	Alfred Wegener Institute for Polar and Marine Research	Germany
8	University of Alaska	USA
9	National Snow and Ice Data Center, University of Colorado	USA

5th Framework Programme

6C - Carbonate Chemistry, Carbon Cycle and Climate Change (a multidisciplinary view)

EVK2-CT-2002-00135

http://www.awi-bremerhaven.de/Projects/C6/index.html

Instrument:	FP5 Research Project	Contract starting date: 01/11/2002
Total project cost:	2.389.796 €	Duration: 48 months
EC Contribution:	1.652.751 €	
Organization:	Alfred Wegener Institut für Polar- und Meeresforschung, Bremerhaven, Germany	
Co-ordinator:	Jelle Bijma (jbijma@awi-bremerhaven.de)	
EC Contact person:	Riccardo Casale (riccardo.casale@ec.europa.eu)	

Objectives

The overall objective of 6C is to hind-cast the processes that control the natural interrelationship between the variation in atmospheric pCO2 and climate change on G-IG time scales (by reconstructing temporal and spatial changes in the ocean carbonate chemistry) and to quantify and predict changes in atmospheric pCO2 on anthropogenic time scales (by quantifying the negative feed-back of pelagic calcifiers).

Intermediate scientific achievements

Among the most important challenges remaining to be addressed by Quaternary palaeoceanographers is the mechanism responsible for lowering pCO2 during the Last Glacial Maximum (LGM) and possible feedback mechanisms with climate change. For over 20 years, scientists have tried to assess the impact of the different "carbon pumps" (physical, organic carbon, alkalinity) separately but contradicting results between the emerging scenarios have failed to explain the natural processes controlling the inter-relationship between the ocean carbon cycle, atmospheric CO2 and climate change. 6C follows a novel approach: Each of the scenarios that have been proposed to explain the glacial-interglacial (G-IG) pCO2 change will eventually lead to a reorganisation of the carbon inventory of the ocean. This leaves a specific "fingerprint" in the oceanic carbonate chemistry which is recorded by proxies that are preserved in the geological archive. We use a multi-proxy approach in order to reconstruct the oceanic carbonate chemistry over the past 130,000 years on selected, well-dated and high resolution cores. The evolving scenarios will be evaluated by regional and global carbon cycle modelling.

Using planktonic and benthic foraminifera we reconstruct the carbonate chemistry of the surface and deep waters. Changes in their chemistry with latitude and over time will allow a reconstruction of changes in the vertical and meridional carbon fluxes during climate change and can be used as a first order approximation of the dominant processes involved. For instance, estimation of changes in DIC and alkalinity of the surface and deep ocean will help differentiate between changes in the export flux of Corg and carbonate alkalinity from the surface water. Thus, we will be able to monitor changes in the Rain Ratio. Under the Rain Ratio hypothesis, there would be a significant ocean-wide increase in the surface and deep ocean alkalinity. Thus, reconstruction of the oceanic carbonate chemistry will allow us to identify the relative importance of biological versus physico-chemical processes. Additional proxy information on the efficiency of the different carbon pumps will allow further interpretation of these processes. For example, analysis of δ15N or Cd/Ca will help us to constrain changes in nutrient utilization.

We will test the validity of the various hypotheses by reconstructing the carbonate chemistry on an ocean-wide scale with all the available geochemical proxies. Temperature estimates of the surface waters, necessary to convert ocean [CO2]aq to atmospheric pCO2 using Henry's law, will also be based on three independent methods (δ18O, Mg/Ca and U 37 k'). As the carbonate system will be over-determined we will be able to verify the proxies against each other. For instance, δ11B based paleo-pH estimates can be quantitatively evaluated against pH changes calculated from Ba/Ca (for alkalinity) and Size Normalized Weights (for [CO3 2-]).

In the first two year of the project we have worked on four cores in the North Atlantic, one core in the Southern Ocean and three cores in the Indian Ocean. Multiple proxies have been analysed and a reconstruction of the carbonate chemistry at those sites is underway.

Socio-economic relevance and policy implications

At this stage it is difficult to point out specific benefits in this area. However, the emerging results and conclusions at the end of the project will aid us in the understanding of the natural controls and feedbacks between the carbon cycle and global climate change. The mechanistic understanding of the natural inter-relationships is a prerequisite to project possible future climate change scenarios and this is an issue relevant to society as a whole and for policy makers in particular.

Partners

N°	Organisation	Country
1	Alfred Wegener Institute for Polar and Marine Research, Bremerhaven	Germany
2	Physikalisches Institut, Westfälische Wilhelms-Universität Münster	Germany
3	Nederlands Instituut voor Onderzoek der Zee, Den Burg	Netherlands
4	University of Cambridge, Department of Earth Sciences	UK
5	Alfred Wegener Institute for Polar and Marine Research, Bremerhaven	Germany
6	Alfred Wegener Institute for Polar and Marine Research, Bremerhaven	Germany
7	Université de Liège, Institute d'Astrophysique et Géophysique	Belgium
8	Université de Liège, Institute d'Astrophysique et Géophysique	Belgium
9	University of Southampton, School of Ocean & Earth Science	UK
10	Nederlands Instituut voor Onderzoek der Zee, Den Burg	Netherlands
11	Alfred Wegener Institute for Polar and Marine Reseach, Bremerhaven	Germany

AICSEX - Arctic Ice Cover Simulation Experiment

EVK2-CT-2000-00078

http://www.nersc.no/AICSEX/

Instrument:	FP5 Research Project	Contract starting date: 01/01/2001
Total project cost:	2.424.255 €	Duration: 38 months
EC Contribution:	1.700.000 €	
Organization:	Nansen Environmental and Remote Sensing Center, Bergen, Norway	
Co-ordinator:	Ola M. Johannessen (ola.johannessen@nrsc.no)	
EC Contact person:	Georgios Amanatidis (georgios.amanatidis@ec.europa.eu)	

Objectives

The overall aim of AICSEX is to compare the natural variability and trends during the last century, for selected observed climate sensitive variables and coupled global/nested climate models, in order to assess the model capabilities for prediction of climate changes in the Arctic, Nordic and Baltic Seas in this century. In the last period, the project focussed on completing the simulations and assessing the performance of the models used. Furthermore, the economic impact of a melting Arctic ice cover was assessed for fisheries, shipping, offshore and hydroelectric energy industries through a project dedicated industrial users reference group.

Scientific achievements

The work on AICSEX has resulted in the following achievements:

- New data sets for surface air temperature and multiple sea ice parameters in Arctic and its regional seas, as well as new data sets for snow cover and river runoff in Eurasian.
- New knowledge of the spatial and temporal variability of temperature and sea ice, through analyses of these new data sets.
- A new high-resolution coupled Atmosphere Ocean General Circulation Model (AOGCM) for the Arctic and its regional seas.
- A new coupled model (physics-biology-geochemistry) for carbon cycle simulations for the Arctic and its regional seas.
- An assessment of the economic impact of climate change on important sectors such as fisheries, offshore industry and power market.

During the last year of the project, we have also completed 5 major papers for international referee journals (4 published, 1 in press), 1 book and 5 book chapters. In addition, 4 journal papers have been submitted to referee journals, and 3 more papers are in preparation. These publications are listed in Section 2.1.

Socio-economic relevance and policy implications

Improvements in our ability to detect and predict regional climate and environmental change patterns improves our understanding of the various possible impacts on economic activity following changes in climatic conditions. In a long-term perspective, climatic changes will indirectly or directly bare consequences for all economic activity on a global scale. Such changes will impact consumer and producer behaviour in a wide range of markets. Change in weather conditions will give rise to change in housing requirements etc. However, the impact may first be seen in markets and economic activity

directly related to the geographic areas where the changes are most distinctive. The impact will probably be first seen in economic activity in the north-east Atlantic. Several European economic activities are dependent upon the climatic conditions in this area: fisheries, marine transport and energy resources, including hydroelectric power production.

AICSEX has been dedicated to the determination of variability and trends for climate sensitive variables. Furthermore, we have used models for prediction of variables in order to assess if abrupt changes of the sea ice cover of the Arctic and Baltic Seas will occur in this century. Climate change is an international issue of great relevance and significance across Europe and beyond. Climate and ocean phenomena and their variability transcend national boundaries, as do their effects on the environment. European climate is associated with regional atmosphere-ocean variations. The inter-relationships between these phenomena and the variability of e.g. sea ice and run-off are certainly manifested on a regional scale. Climate changes are anticipated to be heterogeneous across Europe. Because of positive feedback mechanisms in the Arctic, the northern European regions are expected to be more affected by climate change and their marginal environment more susceptible to its effects.

AICSEX's contribution to European policies is manifold. First, it contributes towards expanding European scientific expertise in global climate change research in Arctic and sub-Arctic regions. It provides more definitive and convincing evidence ("fingerprints") of natural variability and anthropogenic climate change for the high latitudes on the Northern Hemisphere. Europe need to have a clear view of what is happening with global warming in global climate change policy-making, e.g. input to IPCC and Kyoto type protocols. Second AICSEX contributes towards determining, understanding, assessing and predicting climate change patterns that influence the European environment, which have impact on e.g. fisheries, marine transportation, water resources and off-shore oil industry in Arctic and sub-Arctic region. Therefore the results of AICSEX are useful for European Policymakers.

Conclusions

During the last year of the project, a number of major publications from the project have been completed. The main conclusions are:

1. First, we theorise that the Arctic warming in the 1920s-1030s and the subsequent cooling until about 1970 are due to natural fluctuations internal to the climate system. Second, we believe there are strong indications that natural processes alone can explain neither the warming trend nor the decrease of ice extent and volume over the last two decades. Third, the state-of-the-art ECHAM4 (WP6) and HadCM3 coupled climate models both predict a dramatic decrease of the ice cover, which could result in a nearly ice-free Arctic Ocean during summer at the end of this century.

2. Though a climate change may shorten the ice season in the Baltic Sea, the natural variability will be still large. Even in the future on the perspective of decades, there is a need to be prepared for severe ice conditions. The overall tendency towards milder ice winters in the northern Baltic Sea does not necessarily mean that every winter would be mild and, in terms of winter navigation, easy. Considerably year-to-year variability in ice conditions will still to be expected.

3. Over the last 20 years passive microwave satellite data exhibit significant decreasing trends in snow extent found in Eurasia and North America, especially after 1988. The computed linear trends show a marked difference between North America and Eurasia, with a larger decrease in Eurasia than in North America. This tendency is confirmed when analysing the trends in the spring timing of the snow pack disappearance. Spatio-temporal variability is pronounced during the spring melt period. In most parts of Eurasia and the central and

western parts of North America, the tendency has been for earlier snow melt. However, a large region in North-Eastern Canada exhibits a cooling trend with the spring snow pack disappearing later now than 20 years ago.

4. In situ and satellite-derived estimations of the Ob' river discharge at Salekhard (Russia) has been compared and it is shown that Topex/Poseidon data can be successfully used for hydrological studies. The accuracy of the water discharge is good enough to estimate the daily, monthly discharges and annual water flow with an average error of 5%. For mean monthly discharges, the average errors increase to 15%, mostly due to the scarcity of valid Topex/Poseidon observations during some periods and cater discharge overestimation during the water depletion period in August-October. The introduction of new retracking algorithms for computing the river level will significantly increase the accuracy of the discharge estimates.

5. The Arctic is extremely vulnerable to observed and projected climate change and its impacts. The Arctic is likely to experience more rapid and severe climate change than any other region on Earth. Over the next 100 years, climate change is expected to contribute to major physical, ecological, social and economic changes, many of which have already begun. Changes in polar climate will also affect the rest of the world through rising sea levels and increase warming of lower latitudes. Reduced sea ice cover will increase shipping opportunities and access to resources. Marine and terrestrial animal species' diversity, ranges, and distribution are likely to change, some dramatically. Also, the production of hydropower will change with changed patterns of precipitation and temperatures.

6. A partial equilibrium model for the Nordic electricity market has been developed. The model comprises 9 regions of which 6 are endogenous Nordic sub-markets (2 Norwegian, 2 Danish, 1 Swedish and 1 Finnish) while 3 are exogenous regions (Russia, Poland and Germany). All explicit production takes place in the internal regions while the external ones only exchange power with internal regions at fixed home market prices. There are no other limits set to the external supply than the transport capacities. The model operates at regional wholesales level, and simulates a full year production and consumption with the year divided into totally 24 periods, covering 12 months with two load sessions (high and low) for each. The model has been successfully tested in a plain, unconstrained version, but further work is needed to handle cases where water constraints are imposed.

AICSEX has contributed to a better understanding of the climate in the Arctic and its regional seas, by synthesising and analysing new and comprehensive data sets for key parameters like surface air temperature, sea ice thickness and extent, snow cover and river runoff. AICSEX has also improved the climate prediction capabilities by developing new high-resolution atmosphere-ocean-sea ice and coupled models for carbon cycle simulations.

Keywords

Climate change, Arctic, Baltic Sea, Eurasia, sea ice, sea ice thickness, sea ice extent, snow cover, river runoff.

Partners

N°	Organisation	Country
1	Nansen Environmental and Remote Sensing Center	Norway
2	University College London, Centre for Polar Observation and Modelling	UK

3	University of Cambridge, Department of Applied Mathematics and Theoretical Physics	UK
4	Université Paul Sabatier	France
5	Finnish Institute of Marine Research	Finland
6	Foundation for Research in Economics and Business Administration	Norway

ASOF-N - Arctic-Subarctic Ocean Flux Array for European Climate: North

EVK2-CT-2002-00139

http://www.awi-bremerhaven.de/Research/IntCoop/Oce/ASOF/

Instrument:	FP5 Research Project	Contract starting date: 01/01/2003
Total project cost:	3.773.650 €	Duration: 39 months
EC Contribution:	1.885.078 €	
Organization:	Alfred Wegener Institute for Polar and Marine Research, Bremerhaven, Germany	
Co-ordinator:	Eberhard Fahrbach (efahrbach@awi-bremerhaven.de)	
EC Contact person:	Georgios Amanatidis (georgios.amanatidis@ec.europa.eu)	

Objectives

The main ASOF-N objective is to establish the components of the global observing system in choke points of the Nordic Seas to determine the fluxes between the Arctic Ocean and the North Atlantic and to understand and predict how they respond to climatic forcing. To achieve this goal long time series are needed. For this purpose the main tasks were to perform the field measurements with a special focus on setting up of the long term measuring arrays of moored instruments and floats:

- WP 1 'Atlantic water pathways' - measurements of the track lines of Atlantic water flow by floats and mapping horizontal distributions of the Atlantic water properties;
- WP 2 'Fluxes across the western Barents Sea' - measurements by the mooring array in the Barents Sea opening and carrying out the hydrographic sections;
- WP 3 'Heat flux through Fram Strait' - currents and temperature measurements by the mooring array in the eastern and central Fram Strait and the high resolution vertical section of temperature and salinity across the strait;
- WP 4 'Freshwater flux through Fram Strait' - currents and temperature measurements by the mooring array in the western Fram Strait and the high resolution vertical sections of temperature and salinity across and along the strait.

The following set of tasks included analysis of data sets, obtained during field measurements in WP1, WP2, WP3 and WP4 in the first year of the project The objective of WP5 'Data Management' was to provide access to the project data and the actual status of field and modelling work and to organize the data flow to the project data centre from all partners. The WP6 'Integration and Synthesis' aimed to develop the adequate water mass classification for Fram Strait including also a description of time evolution of the water mass properties and regional correlations between the observed variables.

Scientific achievements

The field work carried out during the third year of ASOF-N provided repeated hydrographic surveys including vertical sections of temperature and salinity in the observation area (Barents Sea, Greenland Sea, Fram Strait). The ASOF-N mooring arrays maintained during the project provided time series of fluxes in the Barents Sea opening and across Fram Strait. The analysis of the data obtained during ASOF-N in combination with data measured before ASOF-N permitted to describe the longer term variability of the oceanic conditions in the ASOF-N area. On this basis time variability of the water mass properties, heat and volume fluxes were estimated for the three-year long period and beyond. In combination with historical data a nearly decadal time series of fluxes resulted. The variability of volume, heat and freshwater fluxes was analyzed on different time scales from daily to interannual and

nearly decadal ones. The contributions of local and remote forcing to the temporal and spatial changes of flow and temperature fields were estimated, giving the insight into the relationship between variability of forcing and of fluxes. High resolution numerical models for the western Barents Sea (NPI) and the Greenland Sea, Fram Strait and Arctic Ocean (AWI) were implemented and runs covering the ASOF-N period were completed. A refined water mass classification for Fram Strait was derived and the possibility was explored to compute the time evolution of heat and salt fluxes through Fram Strait, using variable assessment of the observational system performance during the deployments resulted in a data return of about 90% during the final phase of the project.

Socio-economic relevance and policy implications

Variability of the ocean circulation and the water mass distribution in the Nordic Seas lead to changes in the volume, heat and freshwater fluxes between the Arctic Ocean and North Atlantic. Changes in these fluxes can have a strong influence on the role of the ocean in the climate system which includes the potential of abrupt climate changes. The climate variability in particular in the northern North Atlantic has a strong impact on the living conditions in Northwest Europe. This includes energy consumption, sea traffic and marine living resources. Therefore a reliable prediction system is of high value to maintain the present living conditions. Prediction requires understanding and modelling of the relevant processes and monitoring key parameters to validate and constrain the models. Since variability of the relevant time scales can be only studied on the base of the long-term time series, ASOF-N aimed to pave the way towards an observing system consisting of a cost effective array of instruments in the key areas for the exchanges between the North Atlantic and Arctic Ocean. The results of ASOF-N will help to design such a system, to give advice for its implementation and consequently contribute to maintain the quality of life in Northwest Europe.

Results from ASOF-N gave background information to the scientific report from the **Arctic Climate Impact Assessment** (ACIA) published in 2005 which is a project of the Arctic Council and the International Arctic Science Committee (IASC) a high level intergovernmental forum. The ASOF-N results are included into reports to **ICES** (the International Council for the Exploration of the Sea), which gives advice to the member countries and helps them manage the North Atlantic Ocean and adjacent seas. ASOF results are a contribution to the formation of the EU-Integrated Project **DAMOCLES** standing for Developing Arctic Modelling and Observing Capabilities for Long-term Environmental Studies. ASOF results underline the need of a sustained observing system in the Arctic and Subarctic regions in the framework of the Global Ocean Observing System (GOOS) and the Global Climate Observing System (GCOS) which can be maintained beyond the time of individual research projects.

Conclusions

The evaluation of the available historical data together with the results of the ASOF-N field measurements and modelling results revealed a significant warming of the Atlantic Water propagating through the ASOF-N region and an increased heat flux into the Arctic Ocean. The data indicate that variations of the fluxes between the North Atlantic and the Arctic Ocean occur on a wide range of time scales and are interlinked between the main passages. The volume and heat fluxes are also controlled by local and remote atmospheric forcing. Both in the Barents Sea Opening and Fram Strait variability of temperature is independent of the variations in the volume flux. The former is dominated by advective processes and depends mostly on the upstream conditions while the latter is related to the local atmospheric forcing. Observed variations in the Atlantic Water pathways (namely intensification/ weakening of the branches of the Norwegian-Atlantic Current) result in the redistribution of the Atlantic Water in Fram Strait and strongly influence the heat transport into the Arctic Ocean. All these changes occur over long time scales and only quasi-continuous measurements over a decade and more give a chance to identify the nature of these fluctuations. Lacking spatial resolution is a problem in spite that

the major parts of the transports occur in relatively narrow boundary currents. Technical problems with the present day equipment require redundancy. New technology available to replace conventional instruments on an operational basis is under development and a design of optimized observational array has been worked out on the basis of the ASOF-N experience.

Keywords

Fram Strait, Barents Sea, heat flux, freshwater flux, Atlantic water inflow, Arctic Ocean-North Atlantic exchange, moorings, floats, CTD sections

Partners

N°	Organisation	Country
1	Alfred Wegener Institute for Polar and Marine Research	Germany
2	University of Hamburg, Institute of Oceanography, Center for Marine and Climate Research	Germany
3	Institute of Marine Research	Norway
4	Finnish Institute of Marine Research	Finland
5	Polish Academy of Sciences, Institute of Oceanology	Poland
6	Université Pierre et Marie Curie, Laboratoire d'Océanographie Dynamique et de Climatologie	France
7	Norwegian Polar Institute	Norway

ASOF-W - Arctic-Subarctic Ocean Flux-Array for European Climate: West

EVK2-CT-2002-00149

http://www.ifm.uni-hamburg.de/~wwwro/ASOF/

Instrument:	FP5 Research Project	Contract starting date: 01/02/2003
Total project cost:	1.987.679 €	Duration: 30 months
EC Contribution:	1.333.081 €	
Organization:	University of Hamburg, Inst. of Oceanography, Hamburg, Germany	
Co-ordinator:	Jens Meincke (meincke@ifm.uni-hamburg.de)	
EC Contact person:	Georgios Amanatidis (georgios.amanatidis@ec.europa.eu)	

The problem

This project centred on the fact that the climate of NW Europe, the Nordic Seas and Scandinavia is already abnormally warm for its latitude, and is correspondingly sensitive to change in the factors that are responsible for it. We expect that the changes of climate in this sector may be both rapid and radical as we move from the most extreme development of the atmosphere driving in the 1990s to what must surely be the most extreme anthropogenic contribution to climate change in the next Century. Learning how to mitigate the socio-economic effects of these changes requires the development of believable predictive models of the main processes at work. A central requirement for model improvement is the availability of time series measurements of the oceanic heat and freshwater exchanges between the Arctic and the North Atlantic.

The scientific objective

The spread of warmth to high latitudes in the Atlantic sector is due to a complex ocean-atmosphere interaction, which includes a vast amount of heat (about 1015 W) carried northward by the ocean's Thermohaline Circulation (THC). There is growing concern that "global warming" will be accompanied in our sector by strong regional cooling across Northwest Europe and Scandinavia due to slowing of this THC loop. This disruption is likely to take effect through the processes that control the deep overflows of dense water, which drive the THC, and the surface freshwater fluxes from the high Arctic that are supposed to shut it down. The North Atlantic Oscillation (NAO) as the main mode of recurrent atmospheric behaviour in our sector is heavily implicated in these changes and is predicted to amplify with future greenhouse gas forcing. For this reason, the ASOF-W Project has been designed to meet the following overall objective:

> To measure the variability of the dense water and freshwater fluxes between the Arctic Ocean and the North Atlantic in the critical location off Southeast Greenland with a view to understanding and predicting their response to climatic forcing, especially to the NAO.

Clustering of ASOF-W with the two parallel EU FP 5-projects ASOF-N and ASOF-E has assured, that the time-series measurements cover all of the fluxes through the Nordic Seas in a synoptic manner. This effort on the European side has prompted parallel field activities in North America for covering fluxes from the Arctic through the Canadian Archipelago into the North Atlantic.

The approach

Time series measurements have been carried out on the shelf and the slope off Southeastern Greenland by means of two arrays of sensors for currents, temperature and salt to obtain fluxes and flux-variability of the dense Denmark Strait overflow and the freshwater export from the Nordic Seas to the North Atlantic. The overflow measurement array over the slope has been successfully installed during the EU-VEINS project and has been extended to a decadal record by this project. The measurement of the freshwater flux on the shelf in the liquid phase has never been achieved directly before the start of this project. Novel instrumentation has been developed and was deployed in a shelf array to measure the profiles of water speed, temperature and salinity from the drift ice covered surface layer to the bottom.

Major results

The need to resolve the problem of fluxes and flux-variability arises from the fact, that it is now that the atmospheric driving of the northern North Atlantic has seen the strongest signals ever recorded in the time scale range from interannual to decadal. The response to these signals is presently propagating through the high-latitude oceanic-system and has just begun to affect the headwaters of the deep limit of the Atlantic THC. If we had not instrumented the key locations along the paths of these changes, we would have lost the rare opportunity of measuring the oceans response to atmospheric forcing in a phase of an elevated level of signal to noise ratio. This project and its European and North American partners have therefore provided benchmark observations needed to improve coupled climate models. Also provided was the necessary experience for longer-term measurements in high latitude ocean areas in the context of a future ocean observing system. Major results from ASOF-W are listed as follows:

- Despite losses of equipment imposed by the hazardous nature of the East Greenland shelf, a prototype ASOF-W freshwater flux array has been established and maintained beneath a highly variable ice cover. A first liquid freshwater flux estimate yielded a mean value of 2000 km³/yr with a standard deviation of the daily mean estimates of 1.200 km³/yr. This number fitted well into a newly compiled estimate of freshwater fluxes in the Arctic and Subarctic Seas, based on the most recent data available to the project. The freshwater array is continued beyond the duration of the actual project to provide this much needed time series to the upcoming International Polar Year 2007-9 with its activities on the role of the Arctic in the hemispheric water cycle.
- The project continued the time series of direct transport measurements of the dense Denmark Strait overflow with a "picket fence" array of 6 to 8 current meter moorings over the East Greenland slope at 64° N. This array was paired with a bottom-mounted acoustic profiling current meter maintained at the Denmark Strait sill some 500 km upstream. In addition, coupled ocean circulation models with realistic atmospheric forcing were run. The mean transport value from altogether 9 years of array data was calculated to be $4.0 \pm 0.4 \times 10^6$ m³/s with no trend on the decadal time scale and with no correlation to the parallel transport fluctuations of the overflow branches east of Iceland. Significant temperature and salinity signals were recorded with the moored sensors, notably in 1999 and 2004. They could be traced from upstream in the Nordic Seas to downstream to the Labrador Sea, providing information on how atmospherically induced surface anomalies in the high latitudes are advected into ocean depths exceeding 2500 m in the Subpolar seas to the southwest of the Greenland-Scotland Ridge, i.e. the deep headwaters of the THC. As with the freshwater array, the dense overflow array will be continued through the IPY.
- From altogether now 9 years of hydrographic sections worked between the Denmark Strait and the southern tip of Greenland we could provide time series of the downstream development of geostrophic transports of the dense overflow and changes of its water mass characteristics. The transport estimates agree well with the results from the moored array. From the water mass

analysis the persistence of stratification along the overflow plume indicates lesser entrainment rates with the ambient waters than assumed so far.

- The project included a component for the final development, the testing and the field use of a profiling temperature-salinity probe, operated from a bottom mounted winch. Despite considerable engineering progress with the system and ample field campaigns, no scientifically usable data could be obtained. The prototype is continued to be improved. Once operational this instrument is considered ideal for under-ice profiling of shelf waters.
- In a synthesis of the project data the observed variability set the local data into the context of the large-scale climatic signals passing between the Nordic Seas and the deep Atlantic. One of the principal results from our array over a decade of continuous observations is the finding that although the transport time series show distinct interannual variability, there is no obvious evidence for any long term trend in the deep overflow west of Iceland. Models with realistic forcing confirm this. Likewise the recent analysis by the ASOF-E group of the deep overflow east of Iceland over the full record from 1995 to 2005 shows neither evidence for any long term downturn in transport nor an inverse relation to the overflow transports west of Iceland, which is in contrast to earlier reports. Thus we find no evidence yet that deep overflow-transport is directly implicated in the recent reported slowdown of the deep limb of the Atlantic Thermohaline Circulation. Our observations of long term changes in the temperature and salinity properties of the overflows are a different matter and may well be involved in the circulation changes as reported for the lower latitudes. They are certainly involved in the observation of Atlantic-wide changes in salinity. Whereas for our Subarctic region we have analysed a decadal freshening of the ocean fluxes from the Arctic to the Atlantic, there is a corresponding salinification of the upper ocean in the subtropical and tropical regions. This indicates a significant role of the coupled ocean/atmosphere freshwater cycle in linking the high latitude ocean basin with the global ocean. Since this is one of the priority topics during the upcoming International Polar Year 2007-9 the ASOF measurement arrays and data sets provide an important platform to build on for the climate research projects of the next decade.

The ASOF-outreach

The overall aim of ASOF was to implement a longer term system of critical measurements needed to understand the high latitude ocean's steering role in decadal climate variability. This cannot be achieved on a regional basis but can only be met by studying the complete system of oceanic exchanges through the subarctic seas. This need was acknowledged from the outset and it was an extra workpackage added to the ASOF-W project with three main successes: (i) The three components of the European ASOF cluster (ASOF-W, ASOF-N and ASOF-E) were closely integrated by instituting task-groups for planning across all of Nordic Seas and for establishing a system-wide Numerical Experimentation Group. (ii) An international ASOF programme was developed between the EU-groups and relevant North American groups financed through NSF and NOAA, enabling a true pan-Arctic approach to the ASOF-aim. International Steering Committee Meetings, a regular Newsletter and a website have brought together a scientific programme, which has made ASOF the largest ocean-observing network in the hemisphere for the time being. (iii) In anticipation of the upcoming International Polar Year 2007-9, a larger scale context for the ASOF effort itself was achieved by compiling a Science Plan for a pan-Arctic integrated Arctic Ocean Observing System (iAOOS), which was endorsed by the relevant international scientific organizations and accorded lead-status by the International Council of Scientific Unions Joint Committee for the International Polar Year.Partners

Partners

N°	Organisation	Country
1	University of Hamburg, Institute of Oceanography	Germany
2	The Marine Research Institute of Iceland, Division of Oceanography and Ecology	Iceland

3	The Scottish Association for Marine Science, Dunstaffnage Marine Laboratory	UK
4	Department for Environment, Food and Rural Affairs, Cefas Lowestoft Laboratory	UK
5	Finnish Institute of Marine Research	Finland

BALANCE -Global Change Vulnerabilities in the Barents Region: Linking Arctic Natural Resources, Climate Change and Economies

EVK2-CT-2002-00169

http://balance1.uni-muenster.de/

Instrument:	FP5 Research Project	Contract starting date: 01/12/2002
Total project cost:	3.471.724 €	Duration: 39 months
EC Contribution:	2.872.872 €	
Organization:	University of Münster, Institute for Geophysics, Münster, Germany	
Co-ordinator:	Manfred A. Lange (langema@uni-muenster.de)	
EC Contact person:	Maria Yeroyanni (maria.yeroyanni@ec.europa.eu)	

Objectives

The main goal of BALANCE lies in a comprehensive, integrated assessment of the impacts of climate change on environmental and societal components of the Barents region, followed by an assessment of vulnerabilities of the various ecosystems and economies to climate change. This is pursued; on the one hand through the construction of an integrated assessment model, and on the other hand through an integrated network of individual expert models that cover the different components of the Barents system (climate, marine ecosystem, terrestrial ecosystems, economies based on natural resources), Linkages between models had to be identified and feedback runs, and subsequently expert model outputs shall enable feed-back runs of the climate model in order to assess the impact of changing vegetation and sea surface temperature on the projected climate. Major attention had been paid to data integration via Spatial Data Service (SDI), and to the development of the Stakeholder Portal (Assessment and Decision Support System), presupposing close cooperation and efficient data exchange. In order to make findings accessible results shall be broadly disseminated by various means. The objectives of the last period demanded a thoroughly project coordination.

Scientific achievement

Based on the B2 IPCC-SRES scenario two transient climate change runs in 0.5° horizontal resolution had been carried out. As BALANCE aims to project the climate on a detailed regional scale, results from the expert models serve as input for the off-line feedback run of the climate model. Two feedback climate change runs has been performed: one based on data of projected vegetation changes from 1961 to 2099, the second one based on data of projected sea surface temperatures (SST) and on information on sea ice changes from 1995 to 2055. The vegetation feed back run showed that an increased greenhouse gas concentration by the IPCC-B2 scenario leads to a strong warming for the future Barents Sea climate (2080-2099) of about 7°C. The annual mean precipitation shows a clear positive trend and increased about 18.4% for the period 2080-2099 relative to the earlier period 1981-2000. The increase is stronger in winter than in spring and autumn. In summer the precipitation shows a high temporal variability. The definition of linkages between the individual models and their quantification and the specification of vulnerabilities of environmental and socio-economical components of the Barents System comprised elements of the applied methodology. The results of the off-line feedback climate change run with updated SST data indicates that the climate signal is minor compared to the absolute value of the signal. Nevertheless it was shown by the fish model that the projected changes of the marine ecosystem will result in the changing migration and spawning patterns of Cod and Capelin, which in turn can have implications of the fishery sector. An increase in river runoff by 25 % as a result

of altered snow cover and precipitation distributions will have a bearing on near-coastal marine processes.

In addition the terrestrial models project an increase in boreal needle leaved evergreen forest, as well as northwards and upwards extensions, and an increase in total biomass production. Shade-intolerant broadleaved deciduous trees will migrate also northwards and upwards. Shrublands will be replaced by forests, and tundra Plant Functional Types (PFT) will disappear in the Scandinavian mountains. Tundra in Russia will be found further north. Projected future warmer climate will lead to slightly changing timber stocks of Norway spruce and Scots pine, but will result in an increase of potential insect impact, which subsequently will influence future tree composition. Whether or not the Barents Sea Region will become a net sink or source for CO2 cannot be conclusively deduced. A detailed study on a number of bird species indicates that climate change will lead to a loss in habitat and thus a decline in population numbers in the Barents region.

Socio-economic relevance and policy implications

Regarding the investigations on climate impact on economies in the European North the results show the following:

- Forestry: Single extreme whether event, like a storm can have a much larger impact on forest exploitation than a gradual change in climate. This may also have implications on the forest labour market and thus on the regional development. However, the vulnerability to climate change is determined to a significant extent by the adaptive capacities, which in the case of forestry might be high, because of an increasing availability of technology and infrastructure, thus, resulting in a small vulnerability of forest economy to climate change.
- Fishery: Among the fishery resources, cod fisheries dominate the economic exploitation of the Barents Sea ecosystem. North Norway is highly dependent on fish resource utilisation. The results form the modelling efforts regarding aquaculture and fishery show, that the socio-economic relevance in terms of adaptation to the impacts of global warming is small compared to technological means of aquaculture and fisheries management, e.g. the selection of a specific management regime.
- Reindeer herding: This sector is probably the most directly vulnerable in terms of climate change. However, our studies show that traditional adaptation strategies are still pursued and have resulted in relatively modest vulnerabilities to environmental factors. In the countries of Fennoscandia the vulnerability of reindeer herding to climate change is less than expected in Russia. This again is mainly based on the fact that the fennoscandian herders have access to means of adaptation, thus decreasing the vulnerability. Stakeholders, when asked about their view on climate change largely consider it but one (mostly less important) factor determining their future. BALANCE, through its involvement of stakeholders and through the Assessment and Decision Support System makes contributions to the transfer and sharing of knowledge, encouraging and enabling an active rather than a passive adaptation to wider processes of environmental change and thus improving life qualities of communities in the European North.

Dissemination and exploitation of the results

The results of BALANCE have been published in scientific journals, numerous scientific reports and on the Internet through various websites. It should be highlighted that there will be a special issue of the journal "Climatic Change" that exclusively will comprise findings from the BALANCE project. The project and its rationale have been presented at scientific conferences and stakeholder meetings on many occasions. Moreover, a dedicated Stakeholder Portal provides hands-on information and offers ample opportunities for stakeholders to engage in the process of refining adaptation measures derived in exhibition is showed in municipalities of Finland, Norway and Sweden. It is accompanied by a film. All material is to be found at the project web site.

Keywords

Regional climate change and impacts; impact assessment modelling; integrated assessment; adaptation strategies.

Partners

N°	Organisation	Country
1	University of Münster, Institute of Geophysics	Germany
2	SINTEF, Trondheim	Norway
3	Institute of Marine Research, Bergen	Norway
4	University of Utrecht, Department of Physical Geography	Netherlands
5	Royal Swedish Academy of Sciences, Abisko	Sweden
6	University of Turku, Department of Biology	Finland
7	University of Cambridge, Scott Polar Research Institute	UK
8	Natural Environment Research Council, Wallingford	UK
9	Umea University, Department of Social and Economic Geography	Sweden
10	University of Tromsoe, Norwegian College of Fishery Science	Norway
11	Max-Planck-Institute of Meteorology, Hamburg	Germany
12	University of Münster, Institute of Geoinformatics	Germany
13	University of Lapland, Department of Social Studies, Rovaniemi	Finland
14	University of Kuopio, Department of Social Sciences	Finland
15	UNEP-World Conservation, Cambridge	UK

CANDIDOZ - Chemical and dynamical influences on decadal ozone changes

EVK2-CT-2001-00133

http://fmiarc.fmi.fi/candidoz/

Instrument:	FP5 Research Project	Contract starting date: 01/04/2002
Total project cost:	2.414.682 €	Duration: 42 months
EC Contribution:	1.526.336 €	
Organization:	Finnish Meteorological Institute, Arctic Research Centre, Sodankyla, Finland	
Co-ordinator:	Esko Kyrö (esko.kyro@fmi.fi)	
EC Contact person:	Claus Bruening (claus.bruening@ec.europa.eu)	

Objectives

- Reviewing and finalizing the results of the trend studies obtained in the original project period 1.4.2002-31.3.2005.
- Completion of the remaining CTM Decadal integrations
- Analysis of the Unified Model experiments' output to assess the relation between ozone depletion and climate change.
- Completing the synthesis of the project final results: Attribution to causes of the past ozone trends in the Northern hemisphere, Evidence for turnaround of ozone trends as a consequence of the Montreal Protocol. Critical factors affecting future trends of stratospheric ozone. Trend study of CTM ozone output using process oriented statistical model.

Scientific achievements

- Finalization of new ozone data products: Global data sets (satellite and ground based) and re-evaluated local ozone data series.
- Final form of an advanced, process oriented multilinear statistical model to estimate changes and trends and contributing factors in long term ozone time series.
- Final trends in the NH mid latitudes and in the Arctic based on the optimized statistical model and new or re-evaluated data sets.
- Final integrations of decadal model runs using CTMs and Chemistry Climate models: Global decadal 3-D data fields of ozone and other trace gases, Quantification of the relative contributions to ozone change from dynamics and chemistry and estimated polar and mid-latitude ozone loss for different years. Improved understanding of role of stratospheric climate in ozone recovery during next 50 years.
- Attribution of Northern hemispheric ozone trends to chemical and dynamical causes as obtained from statistical studies of long term data sets.
- Assessment of NH long term trend change from negative to less negative and factors behind the change.
- Evaluation of the most critical factors affecting future trends of stratospheric ozone.

Conclusions

The overall outcome from the individual analyses (listed below) shows clearly one common feature in the NH mid latitudes and in the Arctic: Almost monotonic negative trend from late 1970s to mid 1990s followed by a relative recovery after that. An inflection point seems to appear around mid 1990s, somewhat later in the Arctic than in the NH mid latitudes. A similar change can be also seen in the

trends of the Arctic vortex characteristics. Furthermore, all individual analyses point to the changes in dynamical drivers, such as residual circulation represented by EP- or heat-flux from troposphere to stratosphere in mid-/high latitudes, playing a key role in the observed turnaround together with closely associated heterogeneous ozone chemistry represented by PSC volume. Equivalent latitude proxy representing synoptic scale changes in lowermost stratosphere was also a powerful driver of recent recovery locally. In most long term studies where the comparison was made EESC, which since mid 1990s has been leveling off as a consequence of Montreal protocol and its amendments, was observed to represent homogeneous ozone loss better than the simple linear trend. Some influence in recent ozone recovery was also attributed to the solar cycle no. 23.

It was shown in several studies that the polar ozone loss signal effectively spreads out to summer mid latitudes. Because of the correlation between them the impact of the residual circulation- and polar ozone loss proxies are not easily separable in the statistical models. More direct way to calculate dilution is by tracking the depleted air masses by trajectory calculation. This study also shows significant impact of vortex depletion dilutions to NH mid latitudes in April and May, typically 10-40 DU depending on location after cold Arctic winters. Similar results were obtained from the CTM integrations (SLIMCAT with simple PSC chemistry) which showed that the northern middle latitudes 35-60 N can experience reduced total ozone in spring via dilution up to -35 to - 40 DU in cold arctic winters. The trajectory calculation shows further that the dilution may explain about 29 % of the trend in the period 1979-1997 and 33 % of the trend in the period 1979-2002. Since, EESC will remain sufficiently high to sustain massive polar ozone loss in the cold stratosphere for the nearest few decades the dynamics of the NH winter will largely determine both the interannual variability and the development of the long term trend of ozone in the NH mid- and high latitudes.

In this connection also the effect of climate change to the stratospheric temperatures must be kept in mind. Climate/chemistry (with simple ozone scheme) simulations indicated that the observed ozone loss does not affect (through the radiative feedback) the circulation in the NH middle latitudes. In relation to the greenhouse gases radiative feedback, a present ozone and CO2 levels scenario produced an enhanced planetary wave forcing, supporting the CTM's suggestion of a dynamically-driven turnaround.

Keywords

Ozone, ozone trends, ozone loss, ozone depletion, stratosphere, Arctic, Montreal protocol, 3D mode.

Partners

N°	Organisation	Country
1	Finnish Meteorological Institute, Arctic Research Centre, Sodankylä	Finland
2	Swiss Federal Institute of Technology, Institute for Atmospheric and Climate Research	Switzerland
3	University of Cambridge, Centre for Atmospheric Science	UK
4	Université Pierre et Marie Curie, Service d'Aéronomie, Paris	France
5	National and Kapodistrian University of Athens, Faculty of Geology	Greece
6	Institute of Atmospheric Physics of the Academy of the Sciences of the Czech Republic	Czech Republic
7	The Czech Hydrometeorogical Institute, Solar and Ozone Observatory, Hradec Kralove	Czech Republic
8	Danish Meteorological Institute, Middle Atmosphere Physics Research Division	Denmark
9	Alfred Wegener Institute for Polar and Marine Research, Potsdam	Germany
10	University of Oslo, Department of Geophysics	Norway
11	Norwegian Institute for Air Research, Kjeller	Norway
12	University of Bremen, Institute of Environmental Physics	Germany

CONVECTION - Greenland sea convection mechanisms and their climatic implications

EVK2-CT-2000-00058

http://www.damtp.cam.ac.uk/user/ak283/convection-www/

Instrument:	FP5 Research Project	Contract starting date: 01/11/2000
Total project cost:	3.649.465 €	Duration: 36 months
EC Contribution:	2.500.000 €	
Organization:	University of Cambridge	Cambridge, UK
Co-ordinator:	Peter Wadhams (pw11@cam.ac.uk)	
EC Contact person:	Georgios Amanatidis (georgios.amanatidis@ec.europa.eu)	

Objectives

To understand the physics underlying the convection process in the Greenland Sea and how this process links with climatic factors.

Scientific achievements

Previous studies and research programmes in the central Greenland Sea led to a consensus view about how and why the Greenland Sea is such a favourable location for deep convection. This was based on a combination of hydrographic properties and ice formation. The upward doming of the deep waters in the centre of the gyre, which brings the deep waters close to the surface and makes them more easily accessible to surface forcing, has been the main hydrographic feature of the region. The local formation and advection of ice, with net brine release and the establishment of descending plumes, is then believed to lead to deep convective events. Salt flux modelling, backed up by experimental studies of pancake ice formation and brine drainage, supports the concept of ice formation as an important source of negative buoyancy in winter. The field studies planned and executed within the project reflected this basic view by the inclusion of an acoustic experiment for the detection of active plumes and an AUV survey underneath the ice cover. Mesoscale non-hydrostatic modelling studies demonstrate the mechanism by which such plumes can be produced and shows how they could develop.

The experimental results from the project, however, have caused this general picture to be revised through two discoveries. Firstly, the doming in the Greenland Gyre has been superseded in recent years by a pronounced and persistent two-layer structure with a density-salinity step at a depth which has steadily increased to 1600-1800 m. The upper part seems to be completely ventilated each winter, regardless of ice formation or its lack. This leads to the expectation that there might be convection processes different from plume convection, and within the project another main ventilation type has indeed been identified which leads to different, often contrasting effects. A warming of the ventilated layer by winter convection, for instance, was not thought possible before the project, but the new field data show that this can result from a mixed layer-like ventilation mechanism. This ventilation type, which is independent of ice formation, dominated from the late 1990s onward. It is not confined to shallow depth levels but also proceeds to the medium depth density step which permanently limits deeper convection. Consequently, there is not one single main driving mechanism for deep convection, and ice formation is not a necessary prerequisite for it.

The second discovery was of a deep convective chimney near the gyre centre at 75°N0°W, extending to a depth of 2500 m and thus penetrating through the density step described above. The chimney was discovered in March 2001 and was subsequently revisited and remapped by successive CONVECTION

cruises through the summer of 2001, winter and summer of 2002, and spring of 2003, with persuasive experimental evidence that the same chimney persisted, making this the longest-lived such feature yet observed in the ocean. A second chimney was discovered during the spring 2003 survey, which was comprehensive enough to demonstrate that two chimneys are likely to be the total quantity of such features currently existing, in contrast to a larger number which may have existed in the late 1990s as suggested by the motion patterns of neutrally buoyant floats. The 75/0 chimney had a diameter of 10-20 km; was observed to be in anticyclonic rotation at a rate of f/2 out to a radius of 10 km then at a slower rate; became capped in summer by a fresh 50 m surface layer and an intrusion of Atlantic water down to a depth of 500 m leaving a deeper core untouched; and opened up again to the surface each winter. The chimney was also remarkably immobile, moving only a few km between measurements, although in spring 2003 it began a faster movement to the NW. These remarkable discoveries still remain to be embedded in a full synthesis of the convection process. Until we can carry out further experimental observation and theoretical modelling of chimney structure we cannot be sure whether they are playing an active role in the overall convection process, whether they provide a means for deep water formation, or indeed how they are created and maintain such longevity. They come in as a new and unexpected factor in the overall picture of the Greenland Sea convection process.

A question addressed by the project is whether it is possible to identify conditions which are especially supportive of deep convection. Possible local candidates would be strong winds, cold winters, ice formation, or a low inflow of Atlantic Water (AW). Investigations with 1-d model (which is small enough to be run repeatedly with different forcings and initial conditions) revealed that the vertical density structure of the upper water column is the most discriminating factor. The heat content of the AW represents no hindrance, ice formation is helpful but not essential, and moderate heat losses in winter can suffice for deep convection. The vertical density structure of the upper layers is determined not solely by the lateral fresh water input (low saline Polar Waters in the upper few tens of metres) but also by the convection history. This stems from the fact that plume convection usually results in an overall stability increase because of the varying final depths reached by the individual plumes. After winters with plume convection it is usually markedly more difficult to ventilate the affected layer again. A mixed layer-like convection type has the opposite effect by mixing efficiently through large depth intervals. Thereafter, very low stabilities in, say, the upper 1300 to 1800 m facilitate a reventilation during the next winter. A switch back to plume convection, which needs a fresher surface layer, can be caused by a fresh water (Polar Water, ice melt) input. This, again, is naturally sensitive to meteorological forcing.

The larger scale picture of how convection fits into, and is affected by, the larger scale pattern of oceanic and atmospheric circulation in the Greenland Sea – Arctic Ocean system, was addressed by the AWI modelling group. They were assisted by the enormous mass of historical oceanographic and sea ice data collected as another aspect of the project, which is included in this report on a DC-ROM. This provided data to test hindcasts of ice extent, ocean structure and convection back through the century. Remote sensing data, interpreted using innovative algorithms for young ice types and for wave energies, gave new insight into the behaviour and movement of ice within the whole experimental region.

The project has taken our understanding of Greenland Sea convection far beyond the level attained at the end of the previous EU-supported project in this field, ESOP-2. The discovery and mapping of long-lived chimneys, the investigation of how two modes of convection may prevail in different years, the innovative research in acoustic mapping of plumes, in AUV mapping and tank studies of ice, and in large-scale and mesoscale modelling, have enriched our understanding of local and large scale processes. The synthesis of these discoveries into a new way of thinking about the Greenland Sea is now in fertile progress, and is already insistently leasing to a need for new studies. This is a critical region for the control of the Atlantic Thermohaline Circulation and hence the climate of NW Europe, and this project has revealed a new richness and complexity about the processes which go on here.

Socio-economic relevance and policy implications

Much publicity has become attached to the hypothesis that the shut-off of convection in the Greenland Sea will lead to a decline in the vigour of the Gulf Stream and Atlantic Thermohaline Circulation (THC) and a consequent cooling to the climate of NW Europe, estimated in models to take over from global warming as an absolute declining trend by 2100. From the discoveries in CONVECTION it appears that convection in the Greenland Sea is not shutting off, but is taking place in a variety of forms which offer some resistance to a warming trend. This has major implications for modifying our view of how European (and global) climate is set to change over the next few decades, suggesting that the expected shut-off of the THC and cooling of European climate may well not occur and that the models predicting them are too simplistic.

The improved understanding of the physics of convection means that we can return to the models of carbon expert and air-sea CO2 fluxes developed during the earlier EU ESOP project and derive improved estimates of the role of the central Greenland Sea gyre in CO2 sequestration (moderating global warming) and in the carbon budget of the Nordic Seas, of vital importance for fisheries.

The success of the AWI large-scale ice-ocean model of the Greenland Sea – Arctic Ocean system in hindcasting sea ice extent over the past century implies that improved forecasting of sea ice extent in the Nordic Seas over the forthcoming years is now possible. This will allow improved planning for fisheries expansion and for the growth of new trade and oil/or exporting routes from stretches of the Greenland and Svalbard coasts currently inaccessible through sea ice.

Partners

N°	Organisation	Country
1	University of Cambridge (DAMPT)	UK
2	Danish Technical University	Denmark
3	University of Hamburg, Institut für Meereskunde	Germany
4	ISAO-CNR, Bologna	Italy
5	Alfred-Wegener Institut für Polar-und-Meeresforschung	Germany
6	Norsk Polarinstitutt, Tromsø	Norway
7	Danish Meteorological Institute	Denmark
8	IFREMER, Brest	France
9	University of Iceland	Iceland
10	IT IS-CNR, Matera	Italy

CRYOSTAT - CRYOspheric STudies of Atmospheric Trends in stratospherically and radiatively important gases

EVK2-CT-2001-00116

http://badc.nerc.ac.uk/data/cryostat

Instrument:	FP5 Research Project	Contract starting date: 01/01/2002
Total project cost:	3.112.440 €	Duration: 48 months
EC Contribution:	1.743.251 €	
Organization:	University of East Anglia	Norwich, UK
Co-ordinator:	William T. Sturges (w.sturges@uea.ac.uk)	
EC Contact person:	Ib Troen (ib.troen@ec.europa.eu)	

Objectives

CRYOSTAT was conceived to undertake the first combined measurements of virtually all significant greenhouse gases (GHGs) (other than water vapour), ozone depleting substances (ODSs), and related trace gases in contiguous firn and ice profiles, spanning as much as 200 years, from both the northern and southern polar ice caps. For many gases this would represent the first attempt to measure their complete atmospheric histories from pre-industrial times to the present day. Using inter-linked computer models of both the transfer of gases from the atmosphere to firn and ice, and the atmospheric transport and chemistry of gases, it was aimed to reconstruct the evolution and distribution of these numerous gaseous species in the global atmosphere (hemispheric scale for the shorter-lived gases, inter-hemispheric and tropospheric-stratospheric distributions for the longer-lived gases). Sources and sinks, both natural and anthropogenic, were to be identified and quantified using novel multiple-isotope analyses, and by using trace gas modelling. These reconstructed trends were to be further used to determine the histories of (a) radiative forcing from the measured GHGs, (b) stratospheric ozone, temperature and halogen loading, and (c) tropospheric ozone and related chemical processes.

Scientific achievements

Three major field campaigns to retrieve firn air and ice spanning 100 - 200 years of atmospheric compositional history were carried out at NGRIP Greenland, and Berkner Island and Law Dome, Antarctica. A continuous two-year experiment to study the transport of gases in to and through firn at Halley, Antarctica was also carried out to improve our ability to reconstruct long-term time trends of the target gases from firn and ice profile.

Analyses of NGRIP firn air showed this to be the most successful Northern Hemispheric (NH) firn air campaign undertaken anywhere to date. NGRIP is less perturbed by *in-situ* chemical effects than previously reported Arctic firn profiles. More than 90% of all pollutant gases are released in the NH, but conditions for preserving trace gases in firn and ice in the North are usually less suitable than in Antarctica (lesser extent of glacial ice, warmer temperatures, etc.). This unique record from NGRIP is, therefore, highly valuable, especially for shorter-lived gases that are mostly confined to the hemisphere in which they are emitted.

Measurements from Berkner Island and Law Dome have also provided essential information. Comparing trends from both hemispheres, furthermore, has yielded considerable information on the origins and atmospheric lifetimes of the gases studied, and on their global distributions. Long-lived ODSs and GHGs can be studied in both Arctic and Antarctic firn. Firn air records tend to be older and

better preserved in the Antarctic. Berkner Island and Law Dome represent very different glacial environments: the former having a relatively low rate of snow deposition and the latter very high. Conformity of reconstructed trends between such different environments provides significant confidence in the reconstructed histories of the gases.

A general and important overall finding of CRYOSTAT has been that our present day atmosphere is chemically entirely different from that of the pre-industrial Earth. Increases – usually large increases - have taken place in the abundance of nearly every gas that we have measured (and we have measured more than sixty), even amongst those that also have natural sources. A few gases have exhibited decreases in the last one or two decades due to changing industrial practices, but still remain above pre-industrial levels. Of the ODSs the only gases with significant pre-industrial concentrations are methyl chloride and methyl bromide, plus a small contribution from chloroform, bromoform and some other minor halomethanes. Of the GHGs, those with pre-industrial backgrounds are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O) and carbon tetrafluoride (CF_4). Non-methane hydrocarbons and oxides of nitrogen (as measured by proxy from increased levels of organic nitrates) have also risen substantially since the mid-1950s: likely accounting for what is reported in other studies as a probable doubling or trebling of tropospheric ozone in the NH during the 20th century.

Some specific outcomes include

- The sum of reactive chlorine in the troposphere and stratosphere from all source gases (CCl_y) has increased almost eight-fold since pre-industrial times, while the sum of reactive bromine (CBr_y) has more than doubled. Effective equivalent stratospheric chlorine (EESC) from a combination of both chlorine and bromine source gases has, likewise, increased during this time by a factor of five.
- Century-long trends of stratospheric ozone and temperature have been derived from the above. The onset of the Antarctic ozone hole in the 1980s has been shown to be accounted for by a model utilising these observed parameters. Ozone loss due to gas-phase reactions reached 40% of pre-industrial values in near-polar areas at about 45 km altitude, although there was evidence for some offset of this damage by 'self-healing' of ozone levels at lower altitudes. Stratospheric temperatures were modelled to have decreased by as much as 7°C by 1998 due to loss of ozone at this altitude.
- The atmospheric lifetimes of many halocarbons are not constant but have varied over time according to their emission histories. In some cases these variations can be pronounced: for example the lifetime of Halon 1301 is calculated to have been 88 years in 1975, but only 58 years in 2002. This has profound implications for the calculation of Ozone Depletion Potentials and Global Warming Potentials.
- The polar trends of halocarbons with lifetimes of less than about a decade are dependent on the location of their principal emissions, as demonstrated by the reconstructed trends of short-lived halon gases. In the case of halons 1211 and 1202 a shift in emissions from North America/Western Europe to China is consistent with observations in the firn air records from Greenland.
- Chloroform has a smaller natural source than previously thought, and has declined in concentration in the last two decades because of changes in paper and pulp manufacture. Other bromine-containing trihalomethanes have previously unrealised anthropogenic sources, possibly from water chlorination.
- The perfluorocarbon "super" greenhouse gases are all almost exclusively of anthropogenic origin, with the notable exception of CF_4. CF_4, however, also has an important source from aluminium smelting, as does C_2F_6. The trends of these two latter gases are, however, changing, as emissions from aluminium smelting decrease while emissions from the electronics industry increase.

- The direct radiative forcing of the halocarbon gases due to their change in concentration from pre-industrial times to 2002 is calculated to be 327 mW m^{-2}. The amount due to the fluorinated "super" greenhouse gases alone (which are not controlled by the Montreal Protocol) is 17 mW m^{-2}. That due to CO_2 over the same period is 1460 mW m^{-1}, for CH_4 486 mW m^{-1}, and for N_2O 156 mW m^{-1}. Radiative forcing due to the super GHGs has, however, been rising at an ever increasing rate, whereas that due to CO_2, CH_4 and N_2O has been rising at a decreasing rate. Furthermore, several of these fluorinated gases have thousand year lifetimes or more, and may become significant in the future in the absence of measures to reduce their emissions.
- Ozone cannot be measured directly in either firn or ice, but increased levels of other gases, non-methane hydrocarbons, and alkyl nitrates, are 'smoking guns' of increased tropospheric NO_x and increased ozone.
- Novel isotopic measurements of CH_4 and CO have shown that man-induced biomass burning has likely been a significant factor in the observed increased concentrations of these gases. In the case of CO this is the first time that a 20th century trend of this gas has been measured. It is an important player in the atmospheric chemistry that affects the lifetimes of other GHGs and ODSs. For CH_4 there is also clear evidence in its isotope ratios for an enhanced loss process due to oxidation by increased levels of stratospheric chlorine.
- Also entirely novel has been the complete isotopic measurements of N_2O (including position-dependent isotope ratios) pointing to the equal importance of natural and synthetic fertilizers as the prime causes of the observed persistent rise in atmospheric N_2O.
- Process studies have allowed a better quantitative understanding of the manner in which gases move through firn and become encapsulated in ice, thereby significantly improving our ability to interpret ice core records, not only for the time period studied under CRYOSTAT, but of all time scales for which glacial records exist. This is now enabling important questions concerning climate-chemistry feedbacks during climatic cycles to be addressed.

Socio-economic relevance and policy implications

Climate change and stratospheric ozone depletion are two of the most pressing environmental problems of the day. The anthropogenic causes of these are largely attributable to emissions of gases from industrial processes, power production, refrigeration, biomass burning, agriculture, etc. CRYOSTAT has shown the extent to which human influences have perturbed the natural, pre-industrial composition and chemistry of the atmosphere to produce the atmosphere that we live in today. It has investigated the sources of individual gases, the relative contribution of natural and manmade sources, and has assessed the contributions to stratospheric ozone destruction and/or atmospheric warming of gases individually and in aggregate. It has shown the ameliorating effects of the Montreal Protocol, but illustrates that conditions are as precariously balanced with regard to ozone hole formation as they have ever been. The majority of GHGs, meanwhile, continue to rise including those with lifetimes that span generations. This provides a firm platform from which to judge the efficacy of continued adherence to the Montreal Protocol and the coming implementation of the Kyoto Protocol, and contributes to the scientific underpinning of them both.

Conclusions

Widespread and dramatic changes in the atmospheric composition of GHGs and ODSs in both hemispheres, and notably the Northern Hemisphere, during the 20th century have been clearly demonstrated by CRYOSTAT measurements.

Keywords

Firn, ice, atmosphere, greenhouse gases, ozone depleting substances, climate change, stratospheric ozone, radiative forcing, atmospheric chemistry, Arctic, Antarctic, ozone, O_3, carbon dioxide, CO_2, methane, CH_4, nitrous oxide, N_2O, carbon monoxide, CO, halocarbons, CFCs, HCFCs, HFCs, PFCs, CF_4, Montreal Protocol, Kyoto Protocol.

Partners

N°	Organisation	Country
1	University of East Anglia, Norwich	UK
2	University of Reading	UK
3	National Center for Atmospheric Research, Colorado	USA
4	CNRS – Laboratoire de Glaciologie et Géophysique de l'Environnement, St. Martin d'Hérès	France
5	State University New York at Stony Brook	USA
6	CEA-CNRS – Laboratoire des Sciences du Climat et de l'Environnement, Gif sur Yvette	France
7	University of Bern	Switzerland
8	Natural Environment Research Council, British Antarctic Survey, Cambridge	UK
9	Max Planck Institute for Chemistry, Mainz	Germany
10	Max-Planck-Institut für Kernphysik, Heidelberg	Germany
11	Commonwealth Scientific and Industrial Research Organisation	Australia
12	British Atmospheric Data Centre, Didcot	UK

ENVISNOW - Development of Generic Earth Observation Based Snow Parameter Retrieval Algorithms

EVG1-CT-2001-00052

http://projects.itek.norut.no/EnviSnow

Instrument:	FP5 Research Project	Contract starting date: 01/01/2002
Total project cost:	4.257.355 €	Duration: 42 months
EC Contribution:	2.589.765 €	
Organization:	Norut IT	Tromsø, Norway
Co-ordinator:	Eirik Malnes (eirik.malnes@itek.norut.no)	
EC Contact person:	Marta Moren Abat (marta.moren-abat@ec.europa.eu)	

Objectives

To develop and validate new and improved multisensor algorithms for retrieving snow and soil parameters from EO data improved for use in global climate study and hydrology, in particular run off and flood prediction

Scientific achievements

The project partners have focused on demonstrations of near real time snow cover monitoring, and demonstrations of earth observation enforced runoff modelling in the present period. Regional scale demonstrations have been performed in Norway, Finland and Austria. EO imagery from Envisat ASAR and MERIS together with data from the Terra MODIS sensor were used extensively. Some remaining work was also completed in work package 1 and 3. Some of the partners performed a last field in the spring, and these campaigns were coordinated with both aerial and satellite acquisitions.

The user involvement in the project has been an important issue in the reporting period. The results from the EO services and the runoff forecasts were disseminated to end-users via the EnviSnow Prototype System and partner specific web pages. End-users, both within and outside the consortium, were also involved through the EnviSnow user workshop held in Vienna in June. Here partners presented the results and presented their vision for future EO based services for snow monitoring and its use in hydrology. The end-users were also actively involved in the market assessment. The results have been presented in numerous journal papers and conference proceedings.

Socio-economic relevance and policy implications

Accurate snow parameter algorithms are in particular needed for hydrological management, hydropower planning, climate monitoring/modelling and meteorological forecast modelling. All countries with seasonal snow cover have to take this into consideration for hydrological management. Snow-cover monitoring is in particular important for flood prediction. Countries with significant hydropower production and regions with seasonal snow cover usually do snow inventory at the end of the accumulation season in order to plan power production. Many companies are also interested in monitoring the melt rate. Climatological applications are mostly related to global and regional climate modelling, while snow plays a similar role in meteorological forecasting models.

Conclusions

Improved methods for retrieving snow parameters from EO data and including these in hydrological modelling of run-off and flood has been successfully tested during the last period of the project. End users have been actively involved in the testing and in the market assessment.

Keywords

Remote sensing, snow, hydrology

Partners

N°	Organisation	Country
1	NORUT IT, Tromsø	Norway
2	Norwegian Computing Center, Oslo	Norway
3	Helsinki University of Technology, Espoo	Finland
4	Institute for Meteorology und Geophysics, University Innsbuck	Austria
5	IFAC, Firenze	Italy
6	Kongsberg Satellite Services, Tromsø	Norway
7	The Norwegian Water Resources and Energy Directorate, Oslo	Norway
8	Verbund, Wien	Austria
9	ARPAV Centro Valanghe di Arabba	Italy
10	Finnish Environment Institute, Helsinki	Finland

EPICA - The European Project for Ice Coring in Antarctica

EVK2-CT-2000-00077

http://www.awi-bremerhaven.de/GPH/EPICA/index.html

Instrument:	FP5 Research Project	Contract starting date: 01/05/2001
Total project cost:	7.058.344 €	Duration: 36 months
EC Contribution:	2.406.164 €	
Organization:	Alfred-Wegener-Institut für Polar- und Meeresforschung, Bremerhaven, Germany	
Co-ordinator:	Heinrich Miller (hmiller@awi-bremerhaven.de)	
EC Contact person:	Ib Troen (ib.troen@ec.europa.eu)	

Objectives

The overall objective of EPICA is to reconstruct a continuous, highly resolved history of global climate and environmental changes from centuries to several hundred thousand years. For this two ice cores are drilled in East Antarctica, one in the central part at Dome C (75°06'S, 123°21'E), the other in the Atlantic sector at Kohnen station in Dronning Maud Land (75°00'S, 00°04'E). The scientific objectives of the two complementary ice-core records are twofold:

- To achieve the best possible characterisation of the rapid changes during glacial and also during interglacial epochs.
- To provide a basis for understanding the mechanisms driving both global climate and the coupled biogeochemical cycles, and give a perspective for assessing current changes and associated feed backs. The longest records from Antarctica will be recovered from central areas of East Antarctica and will be especially suitable for examining the forcing mechanisms driving the principal climatic cycles throughout the most recent geological period. Evidence on the associated responses of the ice sheet will also be obtained, which have implications for global sea-level changes.

Scientific achievements

The project recovered the planned two deep ice cores at Dome C and in Dronning Maud Land (DML). The age of the ice cores, which yet do not reach the bottom of the ice sheet, covers appr. 810,000 (the oldest ice core recovered so far) and 180,000 years, respectively. The preliminary δD record along the entire Dome C core provided the key climate profile to develop its chronology in combination with numerical modelling. Down to 3139m the core represents 740,000 years, including all of the interglacial marine-isotope stage (MIS) 11, which was not completed in the Vostok record, and running through a further three complete 100-kyr cycles. We first note a clear change in the amplitude of glacial-interglacial changes before and after MIS 12, and by consistently lower maxima. As in the marine-isotope records, the most striking feature is this greater amplitude of glacial-interglacial change in the period after termination V (appr. 430,000 ago). The variations of the atmospheric CO_2 and CH_4 concentrations were also reconstructed through this termination. The overall characteristics of the DML and Dome C stable isotope records look very similar. The difference in $\delta^{18}O$ or δD values between Last Glacial Maximum and the Holocene optimum is comparable, whereas the variations in the glacial are larger in the DML core than in the Dome C core, indicating the influence of the South Atlantic. Temperatures for the Dome C site and the precipitation source area were reconstructed resulting in different trends during the glacial.

The low frequency deuterium-excess fluctuations are strongly influenced by earth obliquity and show a remarkable similarity with a high-resolution southeast Atlantic sea-surface temperature record. By comparing the Dome C isotope record with Vostok and Dome Fuji records, it was found that the East Antarctic climate was homogeneous over the last 80,000 years. The new EPICA ice core records clearly indicate that each of the Dansgaard/Oeschger events found in the GRIP ice core has an Antarctic counterpart. This is also confirmed by CH_4 data, which even show that those events were also characteristic for the previous glacial epoch. The relationship between many of the chemical parameters (and hence the environmental parameters they represent) and Antarctic temperature stayed similar over 740,000 years, but some subtle differences emerge. A comparison of calcium (representing dust, and hence a crude proxy for iron) with CO_2 data for Dome C across warm events A1 to A4 within the last glacial period puts a limit on the extent of iron fertilization in the Southern Ocean. Use of high-resolution sulfate profiles to tie the Vostok and Dome C cores together shows that the ratio of the snow accumulation rate at the two sites varies between glacial and interglacial periods. This unexpected result calls for a re-examination of the hypothesis that accumulation rates are determined only by the site temperature.

The synchronisation of the EPICA cores with the Taylor Dome core using CO_2 concentrations shows that there are accumulation rate changes on some Antarctic locations. Significant advances were made in explaining the meaning of sea salt concentrations in ice cores. The sea ice surface, rather than open water, is a significant source of the sea salt seen in the cores. This opens up the possibility that, on long timescales, the sea salt concentration in ice cores can indicate changes in sea ice productivity. An interpretation of sea salt in the DML core has allowed an estimate of the persistence of the Antarctic Circumpolar Wave to be made over a 2000 year time period. For the greenhouse gases CO_2, CH_4, and N_2O detailed records between 220,000 and 200 years BP are available in unprecedented resolution and precision. The CO_2 record over the transition from the last glacial epoch to the Holocene is so detailed that it provided important information about the mechanisms responsible for the CO_2 increase. Remarkable are further the reconstruction of the CH_4 minimum at 8200 years BP. It was also possible to evaluate a more precise interpolar gradient of the atmospheric CH_4 concentrations. The Dome C record for $\delta^{13}C$ on CO_2 exhibits, besides a general increase of about 0.15 ‰ over the Holocene, three millennial scale variations of the order of a few tenths of a permil, which are unexpected, based on model calculations. It appears that the $\delta^{13}C$ results are much less affected by fractionation during incomplete gas extraction than CO_2 concentration measurements. The record suggests that $\delta^{13}C$ could be correlated to the atmospheric ^{14}C concentration.

The $\delta^{15}N$ measurements on N_2 provide information on the thickness of the diffusive firn layer. As has been observed in other cores from low accumulation sites, the $\delta^{15}N$ trend from Dome C for the transition from the last glacial to the Holocene epoch is opposite from that predicted by firn models. The pore space of snow, firn and ice was reconstructed by X-ray micro-computer tomography showing that the original grain size determines the densification rate of polar firn. The grain-size profiles of the two cores show a strong correlation with climate as a result of grain boundary pinning by insoluble (dust) particles. A line scanning system documented the stratigraphy of the ice cores. Scanning electron microscope studies revealed the complexity of impurity distribution in the ice. The climate record on a depth scale from ice cores, has to be transformed to an age scale. As the DML core is drilled on a flank position, effects of horizontal advection have to be taken into account. With a newly developed 3-D thermo-mechanic nested ice flow model the DML core was dated by Lagrangian backtracing carried out by consecutive cubic spline interpolation of a particle's location using the reversed 3-D velocity field obtained from forward experiments. According to the model results the last three glacial cycles are contained within the uppermost 97% depth. The general properties of atmospheric transport towards Antarctica under varying climatic conditions were studied by analysing tracer transit time climatologies based on the concept of tracer age in a LMDZ general circulation model. A state of the art regional

atmospheric climate model has been used to model the climate and mass balance over Antarctica for the period 1957-2002.

Main deliverables

- Deep drilling and recovery of ice at the Dome C (3201m, ca. 810,000 years) and at the Dronning Maud Land (2564m, appr. 180,000 years) drilling sites.
- Continuous δD, $\delta^{18}O$, and deuterium-excess profiles on the Dome C (to 1800m) and DML (to 800m) cores and extension with selected samples down to the bottom of the cores.
- Detailed records for the greenhouse gases CO_2, CH_4, and N_2O for the period 130,000-200 years BP. Beyond the promised data, measurements were also done on selected samples around termination V.
- Detailed record of the most important aerosol components over the last 130,000 years.
- High resolution records of seasonally varying species at the DML drill site.
- Evolution of texture and fabrics, and the 3-D structure of the pore space of firn and ice.
- Modelling the large-scale evolution during the glacial cycles of the Antarctic ice sheet including age-depth relationship for the ice cores.
- Modelling and observation of present day climate variability and of source regions for the precipitation at the drill sites; high-resolution Antarctic climate simulations for key periods within 130,000 yrs BP.

Socio-economic relevance and policy implications

This project has contributed to a comprehensive study of how climate has changed over the last 740,000 years. This, and the detailed studies that underlie it, will provide critical input to improving climate models that will be used to predict future climate. One output that directly relates to policy has been an assessment of the role of iron fertilization in past CO_2 change, clearly suggesting that iron fertilisation is likely to have only a limited role in mitigating future CO_2 increases. EPICA has a triggering impact to the international collaboration within the Antarctic Treaty system.

Conclusions

Most parts of the project reached or even surpassed the promised milestones and deliverables. Good quality ice cores older than 800,000 years are available. The measuring methods are well developed. Important inferences about the nature of climate changes have already emerged and this project will contribute significantly to our understanding of linkages between components of the climate system.

Dissemination of results

The results were presented at national and international scientific conferences, including Euresco-Conferences, and published in peer-reviewed scientific journals. 62 papers were published, 30 are in press and another 17 presently submitted. National and international press releases and press conferences attracted the interest of the public media, which reported frequently about EPICA and paleo-climate studies with ice cores. Selected data are stored in public accessible data bases dedicated to paleo-climate or ice cores.

Keywords

Antarctica, Ice cores, Paleoclimate, Global change, Isotopes, Greenhouse gases.

Partners

N°	Organisation	Country
1	Alfred Wegener Institute for Polar and Marine Research, Department of Geophysics, Bremerhaven	Germany
2	Natural Environment Research Council, British Antarctic Survey, Cambridge	UK
3	Centre National de la Recherche Scientifique, Laboratoire de Glaciologie et de Géophysique de l'Environnement, Saint-Martin-d'Hérès	France
4	Norwegian Polar Institute, Antarctic Section and Polar Climate Group, Tromsø	Norway
5	Utrecht University, Institute for Marine and Atmospheric Research	Netherlands
6	University of Berne, Physikalisches Institut	Switzerland
7	Université Libre de Bruxelles, Département des Sciences de la Terre et de l'Environnement, Faculté des Sciences	Belgium
8	Stockholm Universitet, Department of Meteorology	Sweden
9	University of Copenhagen, Niels Bohr Institute of Astronomy, Physics and Geophysics	Denmark
10	Alfred Wegener Institute for Polar and Marine Research, Logistics Department	Germany
11	Università Degli Studi di Milano-Bicocca, Dipartimento di Scienze dell' Ambiente e del Territorio	Italy
12	Institut Francais Pour la Recherche et la Technologie Polaires, Technopôle Brest-Iroise	France
13	Ente per le Nuove Tecnologie, l'Energia e l'Ambiente (ENEA), Bologna	Italy

EUPLEX - European Polar Stratospheric Cloud and Lee Wave Experiment

EVK2-CT-2001-00119

http://www.nilu.no/euplex/

Instrument:	FP5 Research Project	Contract starting date: 01/05/2002
Total project cost:	3.208.507 €	Duration: 30 months
EC Contribution:	1.930.305 €	
Organization:	Institute for Stratospheric Chemistry	Jülich, Germany
Co-ordinator:	Fred Stroh (f.stroh@fz-juelich.de)	
EC Contact person:	Claus Bruening (claus.bruening@ec.europa.eu)	

Objectives

General objectives are critical tests of current hypotheses for the three key processes of Arctic stratospheric ozone depletion chemistry through measurement-model intercomparisons:

- PSC formation and properties in Lee-wave and synoptic scale PSC;
- Halogen activation on PSC, and;
- Chemical ozone loss.
- These tests should lead to an improvement of the model reproduction of these crucial processes.
- During the project extension period the following tasks were to be completed:
- Finalization of data products from the field campaign.
- Finalization of interpretational studies concerning PSC formation and halogen activation.
- Publication of the results in the peer reviewed literature.

Scientific achievements

1. A comprehensive data set on the chemical and dynamical evolution of the Arctic polar vortex and its surrounding regions has been measured in the January/February 2003 time period. Data sets consist of meteorological parameters, dynamical tracers (partly with isotopic composition), reactive chemical species involved in ozone destruction, and aerosol physical and chemical properties. With few exceptions all data sets have been finalized and archived on the NILU data base and are available to the VINTERSOL and SOLVE-II communities as well as to the public.

2. Observations of particle phase NOy and particle properties under threshold conditions show that small NAT particles can form at very small number densities without pre-existence of ice particles. Since homogeneous nucleation can also be excluded for the probed scenarios the observed NAT rock embryos (most probably a source of large NAT rocks) are likely to form by heterogeneous nucleation (e.g. on meteoritic dust particles).

3. However, the formation of NAT containing particles within lee-wave events was shown to also have a significant potential for the formation of synoptic NAT PSCs and subsequent denitrification in the Arctic region.

4. A good quantitative model reproduction of observed de-/renitrification in the Arctic polar vortex 2002/03 was attained when regarding non-equilibrium conditions for the growth of NAT particles. Observations of lee-wave PSCs confirm the importance of non-equilibrium liquid particles, as predicted

by detailed PSC models; the quasi-Lagrangian sampling of particle composition within these PSCs provides a stringent test of the models.

5. The HalogenOxides (HALOX) instrument (ClO, BrO) was upgraded towards the measurement of the ClO-Dimer (ClOOCl) and of chlorine nitrate, $ClONO_2$. For the first time ClO dimer laboratory calibrations were performed to ensure proper dimer measurements.

6. Independent studies of the measured ClO and dimer concentrations for just one flight and a suitable ensemble of flights, respectively, have consistently revealed more night time ClO than predicted from the established (JPL) equilibrium constant, calling for a smaller equilibrium constant Keq. That points to the fact that there still is a major challenge in the under-standing of stratospheric reactive chlorine partitioning.

7. Intercomparison of measured and modelled ClO suggest that ongoing Cl activation on liquid aerosol particles has been observed and can be reproduced by CLaMS reasonably well.

8. Accumulated observed ozone loss around the 450K potential temperature level from early December 2002 to mid March 2003 amounts to about 1200 ppb. This is somewhat higher than the modelled integrated ozone loss employing standard (JPL) kinetics. However, employing the new ClO/ClO dimer equilibrium constant derived from the EUPLEX measurements and simultaneously higher Bry mixing ratios (as recently reported by Pundt et al.) integrated ozone loss in the observed magnitude can be reproduced within a simple box model.

9. Dynamical features of different scale size and intensity as a result of mixing in of extra vortex air masses can be reasonably modelled and even predicted employing the Lagrangian CLaMS model.

10. For a flight tailored to the observation of the equilibrium between ClO and its dimer in the same air mass measured at daylight and night-time CN measurements show that at some points the air masses have been exactly reencountered in agreement with the meteorological analysis. This experiment shows that such self-Match and consequently also Match flights are possible under appropriate meteorological conditions.

11. During a flight in cirrus clouds at 10km altitude preliminary data from the HALOX instrument indicate enhanced levels of ClO compared to outside the cloud. Also on several ascent and descent manoeuvres shallow enhancements in ClO have been observed between 12 and 14km in altitude. These observations very relevant for the UTLS region are still under investigation.

Socio-economic relevance and policy implications

The thinning of the ozone layer is a global problem and therefore affects all of Europe. The substantial ozone loss that has been observed in the Arctic has affected Europe more than other regions of the Northern Hemisphere. This is due to the fact that the polar vortex often is shifted towards the European sector of the Arctic because of the Aleutian high (a high pressure system over Alaska and Easter Siberia). Therefore it is of strategic importance to Europe to obtain a better understanding of the ozone layer problem in order to enable reliable predictions of its future state. GCM calculations [Shindell et al., Nature, 392, 589 (1998)] predict that the coupling of ozone and climate may lead to far more dramatic ozone loss during the decade from 2010 to 2020 than has been observed during the 1990s. Especially in the Northern hemisphere, the potential for increasing ozone losses exist [Waibel et al., Science, 283, 2064 (1998)]. Thinning of the ozone layer leads to increased levels of UV-B radiation on the ground that has adverse effects on human health, the marine environment, as well as agriculture. The crucial uncertainties for predicting the future development of the Arctic winter ozone layer are those addressed by E_UPLE_X.

The scientific results from EUPLEX considerably enhance in various aspects the potential for improved modelling and even short term prediction of Arctic polar ozone losses to be expected in any ongoing winter season. This in the longer run may enable short term (weeks to months) warnings in case of extremely low ozone columns and consequently elevated UV exposures above the European region in early spring. This is a major contribution to the actions quality of life and health and security.

Conclusions

The results obtained within the EuPLEx project improve our understanding of the processes of PSC formation, denitrification, halogen activation, and ozone loss in the Arctic polar winter and spring. The results provide a major step forward in the representation of the related processes in our models of the Arctic polar winter and spring stratospheric ozone destruction. This means a significant improvement of our capability to predict short term evolutions of the northern hemisphere ozone layer and consequently UV exposure on ground and therefore may enable policy decisions for mitigation in case of severe events.

Keywords

Stratospheric ozone, polar stratospheric clouds, NAT particles, stratospheric denitrification, halogen activation, halogen partitioning, arctic ozone depletion, polar vortex dynamics.

Partners

N°	Organisation	Country
1	Forschungs-zentrum Jülich	Germany
2	Deutsches Zentrum für Luft-und Raumfahrt	Germany
3	University of Mainz	Germany
4	University of Frankfurt	Germany
5	Observatory of Neuchatel	Switzerland
6	Alfred-Wegener-Institute for Polar Research	Germany
7	CNR, Institute of Atmospheric Physics	Italy
8	Istituto Nazionale di Ottica Applicata	Italy
9	Central Aerological Observatory	Russia
10	University of Lancaster	UK
11	Swiss Federal Institute of Technology	Switzerland
12	University of Leeds	UK
13	Norwegian Institute for Air Research	Norway
14	Stratosphere M, Ltd	Russia
15	Institute of Atmospheric and Oceanic Sciences	Italy

EuroSOLVE - Improved understanding of stratospheric ozone loss by collaboration with the SAGE III Ozone Loss and Validation Experiment

EVK2-CT-1999-00047

http://www.nilu.no/projects/theseo2000/eurosolve.html

Instrument:	FP5 Research Project	Contract starting date: 01/01/2000
Total project cost:	2.210.300 €	Duration: 12 months
EC Contribution:	1.250.000 €	
Organization:	Norwegian Institute for Air Research	Oslo, Norway
Co-ordinator:	Geir Braathen (geir@nilu.no)	
EC Contact person:	Georgios Amanatidis (georgios.amanatidis@ec.europa.eu)	

Objectives

1. Quantifying the degree and geographical extent of chemically-induced (anthropogenic) ozone loss in the Arctic vortex during the 1999-2000 winter.
2. Improving our knowledge on the role of lee-wave induced polar stratospheric clouds in the activation of passive reservoir compounds into active forms that destroy ozone.
3. Obtaining a more complete picture of the most important chemical species involved in chemical ozone destruction.
4. Closing the gap between measured and theoretically calculated ozone loss.
5. Creating the best possible synergy between THESEO 2000 and the US SOLVE campaign.

Scientific achievements

The project was divided into four work packages. The results from these WPs can be summarised like this:

WP 1000: Empirical ozone loss

The north polar stratospheric winter of 1999/2000 was one of coldest on record. This led to extensive formation of polar stratospheric clouds that led to activation of the halogen reservoirs. Over the course of the winter the accumulated ozone loss that resulted reached approx. 70% by the end of March at the isentropic level of 475K. This has been shown by several techniques based on ozonesonde observations. A technique based on data from the POAM satellite instrument in combination with passive ozone from REPROBUS gives a loss of 58% up to 15-20 March. However, here the vertical resolution is somewhat coarser than for the ozonesonde data, and the ozonesonde analysis lasted up to 31 March. The absolute accumulated local ozone loss reached a value of 2.6 }0.4 ppmv at ∪=450K on March 31, according to the Match campaign. This value is confirmed by two vortex average techniques that give 2.6 and 2.5 }0.2 ppmv, respectively. This is the largest ozone loss ever observed during an Arctic winter. The ozone column loss has also been calculated by several independent techniques. The Match technique gives a loss value of 114 } 18 Dobson Units (~35% of the total column present in March). This corresponds reasonably well with the 100DU deduced from the combined SAOZ/Reprobus techniques. GOME ozone profile measurements give a loss of 51+/-10% @ 475 K between 25 January and 31 March corresponding to 1.9+/-0.4 ppmv. Here again the vertical resolution is coarser than for the ozone sonde data.

WP 2000: Mountain waves and Polar Stratospheric Clouds (PSCs)

Our analyses show that although the winter 1999/2000 was exceptionally cold and during certain periods relatively large (synoptic scale) areas were below the threshold temperatures for the existence of PSCs, meso-scale temperature perturbations induced by gravity waves still play an important role for understanding the dynamical, micro-physical and chemical processes in the stratosphere winter. Cooling below the ice frost point was possibly a key factor for the formation of the observed large NAT particles which led to rapid denitrification. The general understanding of meso-scale PSCs has further increased through a combination of high-quality Lidar observations, meso-scale gravity wave simulations and detailed box modelling.

WP 3000: Chemical measurements

The measurements and interpretational studies focussing on several key processes controlling arctic stratospheric ozone depletion show:

- The amount of chlorine activation has been directly and indirectly (OClO, HCl depletion) observed at several points in space and time over the winter and generally can be quite well reproduced by current models. The observations of BrO profiles do in general also show good agreement with the modelled profiles. Therefore maximum ozone depletion rates for the halogen cycles can be derived and compared to observed ozone loss rates.
- Currently accepted photochemistry is unable to correctly reproduce the sunset evolution of ClO mixing ratios in January.
- Chemical ozone loss has been observed through February and March. Preliminary model runs seem to underestimate the observed losses.
- Clear signs of denitrification have been observed by several techniques. Observations of gas-phase HNO3 within PSCs can only be explained through NAT or NAD formation.
- Dehydration has been observed by several independent measurements from January into March and seems to have occurred on a synoptic scale.
- Daytime NO2 mixing ratios around 20km still seem to be underestimated by models. On one occasion in January high night-time NO2 mixing ratios in high excess of model results have been observed.
- Diabatic descent of air masses inside the vortex as derived from tracer measurements seems to be reproduced well by the models.
- Intercomparisons of measurement techniques have been carried out and generally quite good agreement between different techniques was observed.

Overall these results do clearly show where our understanding of chemical and physical processes is sufficient and where the most obvious deficits do currently exist. The wealth of new data gathered during the THESEO 2000 campaign can be completely exploited only over the course of the next few years and will certainly lead to more insights into current problems in the understanding of chemical ozone depletion.

WP 4000: 3-D modelling

Chemical transport models are undergoing constant improvements. Sometimes the agreement between models and observations is excellent, other time the models reproduce only 50% of the ozone loss. The results for the THESEO 2000 winter can be summarised like this:

- The extent of chemical O_3 loss inside the polar vortex in 1999/2000 has been quantified. Ozone loss of up to 70% occurred inside the polar vortex at 460 K
- The effect of the widespread denitrification on the ozone loss has been quantified. Denitrification is estimated to have contributed around 21-30% of the modelled loss.
- Preliminary results suggest that in winter 1999/2000, the current versions of the 2 CTMs perform relatively well in reproducing the large observed losses. This is in contrast to previous cold

winters (studied with earlier versions of the models). The reason for this better agreement is being investigated.

Conclusions

The north polar stratospheric winter of 1999-2000 was the coldest on record (lowest mean January temperature at 50hPa in the 40 year FU Berlin temp. record). The degree of ozone loss at 18-20km altitude was the most severe that has been observed (observations started in 1988-89). At this level more than 70% of the ozone was destroyed during the months Jan. through March. Irreversible removal of HNO3 through sedimentation (so-called denitrification) was observed, and model simulations estimate that this process was responsible for 21-30% of the ozone loss. The low temperatures led to synoptic scale PSCs (i.e. relatively large areas were covered with these clouds). Nonetheless it is clear that meso-scale PSCs formed over the Scandinavian mountains (and possibly other mountain ridges) play a role in the ozone depletion processes. Cooling below the ice frost point was possibly a key factor for the formation of the observed large NAT particles which led to rapid denitrification. The general understanding of meso-scale PSCs has further increased through a combination of high-quality Lidar observations, meso-scale gravity wave simulations and detailed box modelling. Preliminary results suggest that in winter 1999/2000, the current versions of the two 3-D CTMs perform relatively well in reproducing the large observed losses. This is in contrast to previous cold winters (studied with earlier versions of the models). The reason for this better agreement is being investigated. The results from the winter of 1999-2000 show that considerable ozone loss is possible also in the Arctic. Experience from earlier winters in combinations with the results from the THESEO 2000 winter shows that the degree of ozone loss depends to a large extent on the temperature conditions in the Arctic stratosphere. The halogen loading will decline only slowly over the next few decades and, as stratospheric winters tend to get colder due to the increase in greenhouse gases, one must expect that even more severe ozone loss can take place in the future (next 10-20 years or so).

Keywords

Ozone, Stratosphere, Arctic, Ozone loss, Ozone depletion, Montreal protocol, Vienna convention, Polar stratospheric clouds, Measurements, Aircraft measurements, Balloon measurements, Satellite measurements.

Partners

N°	Organisation	Country
1	Norwegian Institute for Air Resesarch	Norway
2	Centre National de la Recherche Scientifique, Service d'Aéronomie	France
3	Deutsches Zentrum für Luft und Raumfart e.V., Arbeitsgruppe Lidar	Germany
4	Forschungszentrum Jülich, Institut für Chemie und Dynamik der Geosphäre	Germany
5	University of Leeds, Environment Centre	UK
6	Alfred Wegener Institut für Polar- und Meeresforschung, Forschungsstelle Potsdam	Germany
7	University of Wales Aberystwyth, Physics Department	UK
8	University of Bremen, Department of Physics	Germany

GLIMPSE - Global implications of Arctic climate processes and feedbacks

EVK2-CT-2002-00164

http://www.awi-potsdam.de/www-pot/atmo/glimpse/index.html

Instrument:	FP5 Research Project	Contract starting date: 01/11/2005
Total project cost:	1.904.372 €	Duration: 36 months
EC Contribution:	1.149.535 €	
Organization:	Alfred-Wegener Institute for Polar and Marine Research, Potsdam, Germany	
Co-ordinator:	Klaus Dethloff (dethloff@awi-potsdam.de)	
EC Contact person:	Georgios Amanatidis (georgios.amanatidis@ec.europa.eu)	

Objectives

The target of GLIMPSE is to better identify and model the important key processes of the climate system, including natural variability, than has been done so far using coarse resolution AOGCMs.

GLIMPSE aimed to:

- address and reduce the mentioned deficiencies in the Arctic by developing improved physical descriptions, understanding and parameterizations of regional Arctic climate feedbacks (stable Arctic planetary boundary layer parameterization, cloud-water-vapour-radiation parameterization, land surface and permafrost parameterization, Precipitation minus Evaporation (P-E) feedbacks on Arctic Oceans sea-ice distribution and influence on ecosystems) in regional climate models with high horizontal and vertical resolution;
- apply improved parameterizations of regional Arctic climate feedbacks into coarser resolution coupled AOGCMs and to determine and understand their global influences via atmospheric and oceanic teleconnections and consequences for decadal scale climate variability;
- assess the implications of these results for abrupt climate changes on decadal time scales in the past and in the future, important for adapting to and mitigating climate changes.

Scientific achievements

The main results in the last year of work (months 25-36) are the following.

1. The work quantifies the performance scores of three individual Arctic regional atmospheric models and the scatter among them. The results show differences in the individual performances and considerable scatter among the different models. The results for the pan-Arctic domain simulations emphasize the large influence of the domain size on the simulation results.

2. Three coupled regional model systems of the Arctic have been applied in decadal scale simulations, and with modifications a stable numerical system with a more realistic simulation of the present Arctic climate have been reached. A few key parameters, like sea ice/snow albedo and threshold values for ice growth/decay have been modified from sensitivity runs. The result of the project is an unique ensemble of three coupled models suited for regional simulation in the Arctic domain.

3. By means of simulations with a global coupled AOGCM it is shown that changes in the polar energy sink region can exert a strong influence on the mid- and high-latitude climate by modulating the strength of the mid-latitude westerlies and storm tracks. It is found, that a more realistic sea-ice and

snow albedo treatment changes the ice-albedo feedback and the radiative exchange between the atmosphere and the ocean-sea-ice system.

4. The planetary wave energy fluxes in the middle troposphere of mid-latitudes between 30 and 50°N are redistributed, which induces perturbations in the zonal and meridional planetary wave trains from the tropics over the mid-latitudes into the Arctic. It is shown, that the improved parameterization of Arctic sea-ice and snow albedo can trigger changes in the Arctic and North Atlantic Oscillation pattern with strong implications for the European climate.

5. Analyses of atmospheric variability of the ECHO-G runs have been carried out. The first 500 hPa EOF patterns are similar, revealing an annular structure similar to the Arctic Oscillation. The main feature of the second EOF is the wave train of the Pacific-North America pattern. Differences have been found for EOF1 concerning the explained variance which increases from 18.3% for the standard run to 20.3% for the run using the modified albedo. Furthermore, the strength of the Pacific centre of the AO-like pattern has increased for this run.

6. An assessment of past climatic changes for the period covering the last 500 years is based on newly collected multi-proxy evidence and a review of published data. Tree trunks, peat deposits and lake sediments were collected during summer 2004 and 2005 fieldtrips to the East-European Russian and Central Canadian Arctic.

7. As a result of the new albedo scheme the circulation in the North-Atlantic region is influenced and as a direct result of the reduced absorbed solar radiation over the northern hemisphere the global annual mean temperature decreases compared to the old run. The runoff into the arctic ocean and the P-E budget over the polar cap oceans are not influenced by the new scheme. As in the case of the old run the temporal evolution of the NAO index increases towards predominantly positive values from late 19th century to the end of the 21st century.

8. A 3-dimensional physical-biological coupled model for the Barents Sea region was validated. In order to study the effect of climatic variability and climatic change on the ecosystem in the Seasonal Ice Zone, an established ecological model was coupled to a hydrodynamic-ice model of the Arctic Ocean and the Nordic Seas. The atmospheric inputs used are the NCEP/NCAR Reanalysis data for the period 1990 to 2004 and the ECHO-G simulation data for two time slices choosing negative and positive phases of the NAO-index in a future climate.

Socio-economic relevance and policy implications

Understanding how the earth's climate system "works", documenting its variability and determining the extent to which climate is predictable are scientific challenges that have enormous socio-economic relevance. Because the climate system is an integrated system of interacting components, climate research requires a perspective view. The central objective of GLIMPSE is to find answers to the following questions:

- What are the global consequences of natural changes in the Arctic climate system?
- Is the Arctic climate system as sensitive to anthropogenic and external variations as global climate models suggest so far?

These questions are investigated at the scale of both the Arctic system and global system by improved regional and global climate model simulations. Aside that the Arctic is a significant component of the global climate system, there is growing evidence that the Arctic has a strong influence on and interaction with the European climate as visible in the forced climate runs.

The general aim of GLIMPSE is to improve Europe's ability to assess climate variability and to develop capabilities for prediction on the decadal time scale and on this basis to assist policymakers in their socio-economic decisions on environmental issues. The working packages addressed and reduced the deficiencies of present-day Arctic climate simulations by improving the understanding of Arctic physical processes. The aim to quantify the uncertainty in an ensemble of different model simulations will help to increase the credibility of Arctic simulations. This is a prerequisite for more reliable estimates of future climate change projections.

GLIMPSE delivers high resolution climate simulations for the Arctic and allows to determine the uncertainty in current climate scenarios for past and future European and global climate resulting from physical model formulation.

GLIMPSE assess the risk of changes in regional feedbacks and climate over the Arctic and the European sector and here global implications, assess socio-economic and policy related decisions for abrupt and unexpected climate changes connected with the nonlinear nature of the climate system;

GLIMPSE disseminates the results of GLIMPSE widely and provided a project summary aimed at policy makers and non-technical interested parties.

By means of simulations with a global coupled AOGCM it was shown that changes in the polar energy sink region can exert a strong influence on the mid- and high-latitude climate by modulating the strength of the mid-latitude westerlies and storm tracks. It is found, that a more realistic sea-ice and snow albedo treatment changes the ice-albedo feedback and the radiative exchange between the atmosphere and the ocean-sea-ice system.

The planetary wave energy fluxes in the middle troposphere of mid-latitudes between 30 and 50 °N are redistributed, which induces perturbations in the zonal and meridional planetary wave trains from the tropics over the mid-latitudes into the Arctic. It is shown, that the improved parameterization of Arctic sea-ice and snow albedo can trigger changes in the Arctic and North Atlantic Oscillation pattern with strong implications for the European climate.

Conclusions

The most probably causes for the large disagreements in polar regions are related to unrealistic parameterizations of a variety of feedbacks. Our understanding of the interactions and feedbacks among the components of the Arctic climate system can be significantly advanced by integrating new observations of Arctic climate variables with global and regional coupled A-O-I models.

It was shown that changes in the Arctic exert via atmospheric teleconnections a direct influence on the European climate by computing the vertical component of the Eliassen-Palm flux. The zone of strongest fluxes at 30-50°N is influenced remotely by the amount of the sea ice cover, e.g. Arctic changes directly affect middle latitudes.

Analyses of atmospheric variability of the AOGCM runs have been carried out. The analyses comprise the determination of the dominant large-scale circulation patterns, the determination of climate regimes and their corresponding frequency of occurrence. Analysing the model runs carried out with the ECHO-G model, the control run over 500 years with the new Arctic sea-ice and snow albedo parameterization (C02) as well as the forced run from 1500-1990 with the new Arctic sea-ice and snow albedo parameterization (E02) have revealed 4 climate regimes for the monthly mean winter (DJF) fields of the geopotential height at 500hPa.

Whereas the differences between the two control runs without (C01) and with the new Arctic sea-ice and snow albedo parameterization (C02) did not change the climate regimes themselves, but have lead to increased strengths of the Pacific centres of the climate regime patterns, differences between the control run and the forced run have shown up also in a change of climate regimes.

The four climate regimes detected for the control run C02 are PNA-patterns in its positive and negative phase, the Cold Ocean-Warm Land (COWL) pattern and a pattern consisting in the East Atlantic (EA) pattern in its negative phase over the North-Atlantic/European region and a strong negative anomaly over the northern North Pacific. For the forced ECHO-G run with the new Arctic sea-ice and snow albedo parameterization from 1500-1990 the COWL and EA-pattern have been detected, too. The positive PNA-pattern has appeared as well, but this regime shows some similarities with the positive AO-pattern. As fourth pattern the AO+ pattern has been found, which replaces the PNA- regime of the C02 run.

Even though large high-latitude warming can be expected under future forcing conditions, its identification is hampered by strong internal variability, which is caused by regime transitions and nonlinear dynamics. This implies a considerable degree of uncertainty about the nature of this multi-decadal scale variability and the interaction with anthropogenic changes. The results from the GLIMPSE partners show that there are preferred regimes, but their relative frequency is not constant in time.

On inter-annual to decadal time scales temperature anomalies in Arctic latitudes caused by internal climate variability tend to blur and contaminate temperature anomalies that are generated by external forcing conditions such as anthropogenic greenhouse gas concentration changes or volcanic eruptions. Nevertheless on multi-decadal to centennial time scales the forced runs clearly show the impact of external forcing on long term mean Arctic climate going along with an Arctic amplification of global mean temperature anomalies and also on the changing of circulation regimes during changes in external forcing conditions.

The approach of GLIMPSE to use two AOGCMs with different external forcing and also to use improved Arctic key process parameterizations gives a clear hint of the vulnerability of the Arctic and processes and feedbacks that are related to the cryosphere. The results of GLIMPSE also indicate that even under global warming conditions Pan-Arctic cooling trends up to decadal time scales are likely to be observed, which for sure will not report an end of the warming as the public might assume.

At the level of European politics, scientific improvements of the basic processes responsible for climate change within the earth system provide opportunities to advance diverse environmental, technological, economic, and political agendas.

Keywords

Arctic, climate change, climate variability, process parameterizations, climate projections

Partners

N°	Organisation	Country
1	Alfred-Wegener Institute for Polar and Marine Research	Germany
2	Norwegian Meteorological Institute, Oslo	Norway
3	Rossby Centre, Swedish Meteorological and Hydrological Institute	Sweden
4	Danish Meteorological Institute, Copenhagen	Denmark
5	Stockholm University	Sweden
6	University of Tromsoe, Norwegian College of Fishery Science	Norway
7	Institute for Coastal Research, GKSS Research Center	Germany

GreenICE - Greenland arctic shelf Ice and Climate Experiment

EVK2-CT-2002-00156

http://www.greenice.org/index.htm

Instrument:	FP5 Research Project	Contract starting date: 01/12/2002
Total project cost:	2.426.334 €	Duration: 42 months
EC Contribution:	1.842.255 €	
Organization:	University of Cambridge	Cambridge, UK
Co-ordinator:	Peter Wadhams (p.wadhams@damtp.cam.ac.uk)	
EC Contact person:	Georgios Amanatidis (georgios.amanatidis@ec.europa.eu)	

Abstract

The overall aim of the project was to study the structure and dynamics of the sea ice cover in a critical region of the Arctic Ocean, north of Greenland, and to relate these to longer-term records of climate variability retrieved from sediment cores.

The ice cover in the region is among the thickest in the Arctic, as the sea ice is forced against the north coast of Greenland and the Canadian Archipelago by the transpolar drift stream. This thick and heavily-deformed ice prevents access by even the most powerful icebreakers and has resulted in an almost complete lack of ice, ocean or geological data from the region. The challenge was to determine in what way ice conditions are changing as part of the overall pattern of retreat and thinning seen elsewhere in the Arctic, and at the same time to determine from seabed coring whether such a heavy ice regime, deep inside the ice limits, was ever free of ice during the past two glacial cycles.

The project was an integrated programme of measurements, remote sensing and modelling. Three winter field measurement campaigns were carried out:

Fieldwork in 2003 was aimed at trialling systems and methods for the main ice camp the following year. Efforts centred on the AWI vessel *Polarstern*, specifically during a two-week period when she was moored to a drifting ice floe in the Yermak Plateau area. Aerial campaigns were conducted with the AWI helicopter-borne electromagnetic induction system (HEM) and the KMS swath laser profilometer, mounted on a Twin Otter aircraft. Activities on the ship included intensive ground-truthing using *in situ* thickness measurements, both by drilling (ice augers, hot water drill) and sledge-borne EM. The drift also allowed the development of thickness monitoring buoys based on the measurement of the spectrum of flexural-gravity waves in the ice. Concurrent data were obtained from an ice camp (APLIS) north of Alaska, providing long-range comparisons of waves necessary for testing the buoy concept.

2004 saw the project team install and occupy an ice camp in the Lincoln Sea, north of Greenland, using Twin Otter aircraft. The camp was a novel, low-cost, lightweight effort, which provided an excellent platform for science in this otherwise inaccessible region. The camp was placed 280 km north of Alert (85°N, 65°W), and occupied by 10 scientists for two weeks in May. Activities at the camp included geological investigations of the seabed and sub-seafloor, a co-ordinated aerial thickness measurement campaign, *in situ* measurements of ice thickness and properties, and the deployment of an array of buoys designed to measure both path-integrated ice thickness and drift, hence deformation over the lifetime of the project and beyond.

The opportunity was taken to repeat the HEM and laser measurements north of Alert with a limited campaign in 2005, to examine temporal as well as spatial ice thickness variability in the region.

Partners

N°	Organisation	Country
1	University of Cambridge	UK
2	GEUS, Copenhagen	Denmark
3	KMS, Copenhagen	Denmark
4	Danish Technical University, Lyngby	Denmark
5	University of Bergen	Norway
6	Alfred-Wegener-Institut für Polar- und Meeresforschung, Bremerhaven	Germany
7	University of Iceland, Science Institute, Reykjavik	Iceland

MAIA - Monitoring the Atlantic inflow towards the Arctic

EVK2-CT-1999-00008

http://www.bodc.ac.uk/projects/european/maia/

Instrument:	FP5 Research Project	Contract starting date: 01/01/2000
Total project cost:	2.393.050 €	Duration: 36 months
EC Contribution:	1.183.500 €	
Organization:	SINTEF, Civil and Environmental Engineering, Trondheim, Norway	
Co-ordinator:	Thomas McClimans (Thomas.A.McClimans@sintef.no)	
EC Contact person:	Ib Troen (ib.troen@ec.europa.eu)	

Abstract

The overall objective of MAIA is to develop an inexpensive, reliable system for monitoring the inflows of Atlantic water (AW) to the northern seas. The method employs a geostrophic balance between the Coriolis force on the flow and the pressure (sea-level) difference across the flow for variations that are much slower than a day. Due to the Coriolis effect, the poleward flow causes the surface to rise to the right toward the coast. The flow of AW through the Norwegian Sea comprises an offslope baroclinic transport and a barotropic shelf slope jet. The inflow past the Faroes contains a combined barotropic-baroclinic jet.

MAIA aims to monitor the inflow of AW and associated velocities on the continental shelves to an accuracy of 15% of the total values and a time resolution down to 5 days. This accuracy and resolution, using the proposed method, has been earlier demonstrated for shelf slope currents. The 5-day averaging eliminates the effects of tides and synoptic meteorological effects.

The region of interest extends from the Rockall Trough in the southwest to the Kara Sea in the northeast. In the north, the project focuses on monitoring the flows through the Barents Sea. The effects of the inflows on the ice fronts in the north are studied.

There are several variables to take into account when using the MAIA concept. From earlier work, the buoyancy of the coastal water and the atmospheric pressure (inverse barometer) near the tide gauges are taken into account. This gives the coastal signal of the AW inflow, but both in situ data from 1975 to 2000 and satellite altimetry have revealed several other physical aspects of the ocean circulation that must be considered. These include significant motions in the deeper layer, wind, a buoyant surface layer outside the AW front, variable density of the AW inflow and a variable external water level.

The original paradigm was based on a simple 2-layer flow off Norway, where the barotropic slope jet and the baroclinic frontal jet are geographically separated. The distribution to the north of the Faroes is more complicated, with a mixed barotropic baroclinic slope jet. For this region, it has been possible to resolve the modes using EOF. Here, there appears to be a relatively constant, but noisy, division between baroclinic and barotropic parts throughout the year. This is believed to be a result of the topographical constraints imposed by the Iceland-Faroe Ridge.

Algorithms for computing the inflow were developed in MAIA WP3 (2002) on the basis of historical data from 1975 to 2000. A major result of the historical analysis is the demonstration of disparate, latitude-dependent seasonal phases for the baroclinic and barotropic flows. The algorithms in MAIA WP3 (2002) were linear regressions.

Results from a validation experiment from June 2000 to November 2001 are used to validate the earlier algorithms and to resolve several issues. In general, the early algorithms had very limited predictive capability. In this experiment both currents and bottom pressures are used to estimate the inflows, and drifters and tracers are used to gain insight in the influence of the outer domain. The results have resolved, in part, the seasonal disparities.

In the newer work we have made improvements in the algorithms by accounting for the quadratic relation between baroclinic transports and water level rise across the current, by including satellite altimetry closer to the shelf slope and by accounting for the effect of winds near the coastal stations.

Based on these findings, revised algorithms are proposed and recommendations are made for improvements in the method to capitalise on the available monitoring data. A time series of estimated monthly averaged Atlantic water inflow toward the Arctic is presented for the period 1978-2002.

We have reduced the noise level for predicting flows on the basis of coastal water level data by employing more monitoring data. To reduce the noise further, it is recommended to expand the monitoring by employing telemetering bottom pressure sensors at strategic locations. Bottom pressure sensors located in regions with significant baroclinic flows need the support of inverted echo sounders and seasonal hydrography to record the actual water level.

This report and all other MAIA deliverables are included in the MAIA CD-ROM that is issued by BODC.

Partners

N°	Organisation	Country
1	Institute of Marine Research, Bergen	Norway
2	Natural Environment Research Council, Birkenhead	UK
3	Swedish Meteorological and Hydrological Institute, Norrköping	Sweden
4	Université Pierre et Marie Curie, Paris	France
5	Scottish Office Agriculture and Fisheries Department, Aberdeen	UK

MAPSCORE - Mapping of polar stratospheric clouds and ozone levels relevant to the region of Europe

EVK2-CT2000-00072

http://www.leos.le.ac.uk/mapscore/

Instrument:	FP5 Research Project	Contract starting date: 01/01/2001
Total project cost:	2.204.246 €	Duration: 36 months
EC Contribution:	1.477.423 €	
Organization:	University of Leicester	Leicester, UK
Co-ordinator:	John Remedios (j.j.remedios@le.ac.uk)	
EC Contact person:	Riccardo Casale (riccardo.casale@ec.europa.eu)	

Abstract

The MAPSCORE project is an E.C. Framework 5 study which has sought to advance the exploitation of new and existing datasets for climate change research. In particular, the MAPSCORE aims were to support European Union requirements for continued monitoring and understanding of ozone changes over Europe in connection with Montreal protocol and climate change studies (Kyoto-related). The MAPSCORE programme has been carried out in association with other E.C. projects involved in the Global Atmospheric Observations Cluster (GATO).

The project has brought together twelve key European expert groups who have exploited a number of exciting, recent scientific advances to provide new interpretations of data relevant to stratospheric ozone from European Commission-funded field campaigns and from European/international satellite programmes. Critically, the MAPSCORE project has been able to advance our understanding of Polar Stratospheric Cloud (PSC) formation and the control of ozone depletion in the European region.

Context of the work

A key aspect of MAPSCORE is provision of an assessment of the relation of PSCs to ozone loss rates over Europe, as required by modellers of atmospheric chemistry and climate. The sensitivity of PSC formation to temperature implies a link to cooling of the lower stratosphere induced by changes in greenhouse gases in the troposphere. Subsequent effects on stratospheric ozone levels could be highly significant over the next fifty years whilst stratospheric chlorine loading remains high. The MAPSCORE project demonstrates a strategy for future atmospheric observations as required for global observing systems. The outcomes are the result of working closely with the European Space Agency and with the managers of field campaigns, particularly the European Ozone Coordination Unit. They demonstrate the utilisation of measurements of PSCs, ozone and related chemical species in an integrated manner to further develop the concept of a polar observing system.

Such a system, if supported within the Global Environment and Environmental Security (GMES) initiative, would deliver an invaluable component of a European atmospheric monitoring capability with clear links to the development and implementation of European policy.

The chief applications for which the results of the MAPSCORE project can be utilized are summarized here as:

1. Characterisation of ozone loss in the polar winter stratosphere over Europe during specific winters from 1991/92 to 2002/03.

2. Calculations of radiative transfer, particularly levels of ultra-violet radiation reaching the surface.
3. Implementation of mechanisms for the formation of PSCs in models and investigations of the long term implications for ozone loss.
4. Climate timescale (50 years) links between greenhouse gas warming, temperature in the lower stratosphere and polar/mid-latitude ozone levels in the lower stratosphere.
5. Improved numerical weather forecasting through better specification of stratospheric ozone.
6. Enhanced exploitation of Earth Observation sensors for surface and atmospheric studies.

Two MAPSCORE brochures, a project description and a project results brochure, are available which describe the project in more detail and provides illustrative examples. The MAPSCORE project web-site can be found at http://www.leos.le.ac.uk/mapscore/ .

These activities within MAPSCORE and their applications have been notably enhanced through co-ordination with European and international activities. Liaison within the GATO cluster reinforced the focus of MAPSCORE research and also provided strong links with users through the European ozone co-ordinating office. This is reflected in MAPSCORE involvement in the VINTERSOL planning group, through which the MAPSCORE project closely supported researchers investigating ozone loss in the winter/spring period of 2002/2003 (Vintersol/SOLVE II campaign). Activities included the provision of near real-time and forecast data as well as diagnostic analysis of the evolution of the winter ozone loss and PSCs. The GATO cluster further complemented the MAPSCORE focus on training and research through participation in a workshop on chemical data assimilation. During the MAPSCORE project, major new sources of data arose from the successful launches of the ENVISAT, METEOR/SAGE III and Odin satellites, and added much to current studies of Northern hemisphere ozone processes. Through its international collaborations, the MAPSCORE project has been able to provide a strong exploitation of these datasets, particularly those from the MIPAS instrument on ENVISAT.

Scientific achievements

During the MAPSCORE project, research activities and user support services have been able to deliver a number of very significant advances. The principal achievements have been in the following areas:

1. The modelling of the hemispheric formation of PSC particles in the Arctic;
2. The modelling of denitrification due to PSCs in the Arctic;
3. The use of observations of PSCs and denitrification both at specific locations and for entire vortices;
4. Ozone loss rate calculations for the entire polar vortex;
5. The implementation of user support services for forecast and near real-time information on PSCs and ozone loss.

Chief highlights of the project include the demonstrations of the effects of mountain waves on hemispheric PSC formation, implementation of nucleation mechanisms for NAT particles in non-equilibrium PSC and denitrification models, successful calculations of denitrification with the first three-dimensional, non-equilibrium model, the discovery that a number of cold Arctic winters in the 1990s (1994/5, 1995/6, 1996/7, 1999/2000) were susceptible to denitrification by low number concentrations of large NAT particles, methods for detection and assignment of PSC type for satellite, lidar and SAOZ measurements, first observation of a distinct infra-red spectral signature to PSC particles, determination of PSC properties such as mean size from visible observations, acquisition and databases of refractive indices from laboratory studies, polar ozone loss rate calculations using chemical assimilation models and observation techniques, results from a chemical assimilation system for ENVISAT data, and near real-time and forecast user support services operated during Arctic winter 2002-3.

The MAPSCORE project has providing an important contribution through the E.C. framework V programme supporting exploitation of existing and new datasets for stratospheric ozone research. It has

added considerably to our knowledge of severe polar ozone loss processes and to our understanding of systems that could provide GMES type services in the future in support of Montreal and Kyoto protocol assessment. A large number of publications and presentations have already been made with MAPSCORE results and it is expected that many further papers will follow. These will include a set of papers within the Vintersol/Solve II special issue of Atmospheric Chemistry and Physics.

Partners

N°	Organisation	Country
1	University of Leicester, EOS	UK
2	Norwegian Institute for Air Research	Norway
3	Danish Meteorological Institute	Denmark
4	Institute of Atmospheric Physics	Germany
5	University of Leeds, School of the Environment	UK
6	Rutherford Appleton Laboratory, Atmospheric Science Division	UK
7	ETHZ – Institute of Atmospheric Physics	Switzerland
8	CNR – Istituto di Fisica dell'Atmosfera	Italy
9	Belgisch Instituut voor ruimte-Aeronomie	Belgium
10	University of Wuppertal/Research Centre, Jülich	Germany
11	Université Paris VI, Institut Pierre-Simon Laplace	France
12	Alfred-Wegener Institute for Polar and Marine Research	Germany

Meth-MonitEUr - Methane Monitoring in the European Region

EVK2-CT-2002-00175

www.gl.rhul.ac.uk/METH/MonitEUr/

Instrument:	FP5 Research Project	Contract starting date: 01/02/2003
Total project cost:	590.035 €	Duration: 24 months
EC Contribution:	519.664 €	
Organization:	Royal Holloway Univ. of London	Egham, United Kingdom
Co-ordinator:	Euan Nisbet (e.nisbet@gl.rhul.ac.uk)	
EC Contact person:	Ib Troen (ib.troen@ec.europa.eu)	

Objectives

To create a European methane monitoring network, unifying disparate national efforts, as a valid European contribution to the global problem of monitoring methane. To collect intercompared data suitable for regional modelling of methane in the air over Europe (including European Russia) and Siberia. To link the work with Carbo-Europe and to design a cost-effective sampling network that will enable regional quantification of emissions.

Scientific achievements

Meth-MonitEUr has created an intercompared pan-European methane monitoring system, bringing together national groups from the west of Ireland to the Ob river estuary in Siberia, and also monitoring the Atlantic background from Antarctic to Arctic. The project has monitored methane concentrations in air at ocean ic background stations, in the continental background across Europe, and at selected highly populated urban areas. Carbon isotopes in methane have also been measured and shown to be a highly effective tool in identifying source mix, and for the first time semi-continuous isotopic monitoring has been carried out. Radon monitoring has been set up in two new sites and is a powerful tool in calibrating emissions of methane and other gases.

The monitoring work has been complemented by modelling studies, using a variety of techniques from trajectory analysis to complex 3D models on regional and global scales. The results show that it is in principle possible to use atmospheric data to verify European methane emissions and independently to test emissions declarations, on local, regional and national scale, including for UNFCCC and Kyoto.

Main deliverables

The following have been delivered:

- Methane concentration and methane isotopic time series from stations in Atlantic, Arctic, northern Europe and Russia. Methane and methane isotope measurements are also delivered as time series from selected urban areas, and also field campaign data from Siberian gasfields. Measurement programs have been intercompared across Europe and with international groups. Radon monitors are installed and records are delivered from London and Krakow. The data have been placed in a database for modelling use. Initial regional and global modelling has been carried out.
- Problems in European monitoring have been assessed, and key requirements identified, including monitoring needs and site choice. The work will lead to a European methane proposal at the next opportunity. Co-ordination delivered.

- Scientific publications are delivered, in press, submitted, and pending.

Socio-economic relevance and policy implications

Europe is a major source of methane on a global scale. Methane has up to 60+% of the global warming impact to date of CO_2 (Shindell et al. GRL, 2005) and is a prime target for fast-acting reduction programs. Presently methane emissions across Europe are not well quantified and emissions estimates depend on statistical sources reported by emitters, not on independent air-down measurement. By creating a Europe-wide methane monitoring system, Meth-MonitEUr permits regional modelling and assessment of EU emissions in the global context. Hitherto, much methane work has depended on US measurements (including within Europe). Now Europe can contribute too.

The Meth-MonitEUr project is important both in that it helps assess European and Russian methane emissions, and also as it is a start to verification of agreements such as Kyoto, which presently accept self-declaration of emissions. Successful independent verification of emissions declarations will create trust between emitters and make more likely the success of the agreements.

Conclusions

Meth-MonitEUr is a relatively small and low-budget program but has been very successful in building up a partnership that integrates many groups and permits European methane monitoring to contribute to global greenhouse gas measurement, hitherto in part dependent, even in Europe, on external support.

Dissemination of results

Many scientific publications and presentations published, in press, submitted or in preparation. The Meth-MonitEUr project was presented at the Dec. 2004 meeting of the American Geophysical Union, with discussion with key US methane experts. Several Meth-MonitEUr investigators were invited to the 2003 biannual meeting of the UN World Meteorological Organisation / IAEA Panel of Experts on CO_2 and trace carbon greenhouse gas measurement, and will attend the 2005 meeting also.

Keywords

Methane isotopes, carbon, greenhouse gas, Kyoto

Partners

N°	Organisation	Country
1	Royal Holloway Univ. of London, Egham	UK
2	Stockholm University, Department of Meteorology	Sweden
3	Ruprecht-Karls-Universitaet Heidelberg, Institut fuer Umweltphysik	Germany
4	National University of Ireland, Martin Ryan Marine Science Institute, Galway	Ireland
5	Commissariat à l'Energie Atomique, Laboratoire des Sciences du Climat et de l'Environnement, Gif sur Yvette	France
6	AGH - University of Science and Technology, Faculty of Physics and Nuclear Techniques, Krakow	Poland
7	Finnish Meteorological Institute, Air Quality Research Department, Helsinki	Finland
8	Centre National de la Recherche Scientifique, Laboratoire des Sciences du Climat et de l'Environnement, Gif sur Yvette	France

MOEN - Meridional Overturning Exchange with Nordic Seas

EVK2-CT-2002-00141

http://www.bjerknes.uib.no/pages.asp?kat=74&lang=1

Instrument:	FP5 Research Project	Contract starting date: 01/12/2002
Total project cost:	1.727.606 €	Duration: 36 months
EC Contribution:	1.590.709 €	
Organization:	Bjerknes Centre for Climate Research	Bergen, Norway
Co-ordinator:	Svein Østerhus (svein.osterhus@gfi.uib.no)	
EC Contact person:	Georgios Amanatidis (georgios.amanatidis@ec.europa.eu)	

Objectives

- To contribute to a better long-term observing system to monitor the exchanges between the North Atlantic and the Nordic Seas.
- To assess the effect of anthropogenic climate change on the Meridional Overtuning Circulation.

Scientific achievements

The two years of data from the MOEN moored current meters measurements and CTD cruises are added to the existing data bank and the volume flux of Atlantic inflow between Scotland and Greenland was estimated for the period 1994 to 2005. Averaged over the years 1997 to 2005, values of volume for each of the three branches are estimated as 0.8, 3.7 and 4.2 Sv for the Iceland, Faroe and Shetland branches. The total Atlantic inflow across the Greenland-Scotland Ridge into the Nordic Seas is estimated to 8.7 Sv. The average volume flux of the dense Faroe Bank Channel (FBC) overflow is about 2 Sv with a seasonal variation, inter-annual variations are also seen, but no persistent trend can be discerned for the decade of observations.

By applying the MOEN coupled ocean-sea ice model system a total of 26 hindcasts have been produced for the period January 1948 to June 2005. The computed volume fluxes are very similar to the measured fluxes for the three Atlantic inflow branches and the same is the case for the Iceland Scotland overflow. Such a high degree of correspondence clearly indicates that both the measurements in the monitoring system and the model results are able to describe the natural variations accurately.

Socio-economic relevance and policy implications

- MOEN has extended the time series of Atlantic inflow to the Nordic Seas and dense overflows through the Faroe Bank Channel with two yeas. The new measurements have been combined with historical data to construct a decadal long time series of transport of the warm and salty Atlantic water toward the Arctic and the return of cold dense overflow.
- MOEN has developed a model tool capable to describe the observed volume transport.
- MOEN has designed an optimised monitoring scheme for long-term monitoring of the exchange across the Iceland-Scotland ridge. The basic tools for achieving a sustainable monitoring system are moored, ship- space-born instrumentation used to collect the necessary field data.

Conclusions

- The MOEN field phase was successfully terminated in 2005 with a data return close to 100%.
- MOEN modelling results show that the model is able to describe the observed natural variability and exchange variation with high accuracy.

- Ten peer-review articles have been publish including two high impact papers in Science and Nature.

Keywords

Atlantic Ocean; Nordic Seas, fluxes; dense overflows; current measurements.

Partners

N°	Organisation	Country
1	Bjerknes Centre for Climate Research	Norway
2	The Scottish Association for Marine Science	Scotland
3	Marine Research Institute, Reykjavik	Iceland
4	Danish Meteorological Institute, Copenhagen	Denmark
5	University of Hamburg, Insitute für Meereskunde	Germany
6	Stockholm University, Department of Meteorology	Sweden
7	University of Copenhagen, Niels Bohr Institute for Astronomy, Physics and Geophysics	Copenhagen
8	The Faroese Fisheries Laboratory	Faroe Islands
9	Fisheries Research Services Marine Laboratory, Aberdeen	Scotland

NOCES - Northern ocean-atmosphere carbon exchange study

EVK2-CT-2001-00134

http://www.ipsl.jussieu.fr/projets/noces/

Instrument:	FP5 Research Project	Contract starting date: 01/04/2002
Total project cost:	2.324.197 €	Duration: 36 months
EC Contribution:	1.582.774 €	
Organization:	CEA-CNRS – Lab des Sciences du Climat et de l'Env, Gif sur Yvette, France	
Co-ordinator:	James Orr (orr@cea.fr)	
EC Contact person:	Claus Brüning (Claus.Bruning@ec.europa.eu)	

Objectives

1. To assess spatiotemporal patterns and associated uncertainties of intrannual-to-decadal variability of air-sea CO2 exchange, particularly in the northern hemisphere, by means of diagnostic ocean model comparison and data evaluation;

2. To evaluate how different prognostic coupled carbon-climate models perform for the ocean component on the most relevant time scale: interannual-to-decadal variability; and

3. To improve constraints on the terrestrial carbon sink over Europe, using simulated air-sea CO2 fluxes and uncertainties as a priori estimates for inverse atmospheric models.

Scientific achievements

- Production of standard protocols with which ocean modellers are now able to make comparable simulations of interannual to decadal variability. The NOCES/OCMIP-3 protocol document has become a standard in the community.
- Production of a detailed multi-model output archive from the standard ocean model simulations made within NOCES. This legacy from NOCES will serve the community as a standard reference point for many years to come. Will be more valuable due to efforts to improve the common protocol guidelines.
- Improved atmospheric inverse modelling approach.
- Improved method to evaluate the variability of air-sea CO2 fluxes from ocean models vs. atmospheric inverse models [*Peylin et al.*, 2005].
- Improved understanding of what controls tropical Pacific carbon and radiocarbon [see NOCES publication *Rodgers et al.*, 2004].
- Improved understanding of temporal trend in observed pCO2 in the North Atlantic [see NOCES publication *Lefèvre et al.*, 2004]
- First evaluation of decadal variability of air-sea CO2 fluxes in the North Atlantic [see NOCES publication *Raynaud et al.*, 2005].
- Better understanding of compensating regional variability of air-sea CO2 fluxes in the North Atlantic basin. The North Atlantic's subtropical gyre was not the largest contributor to the overall, basin-wide variability, in contrast to previous suggestions. The subpolar gyre and the inter-gyre region (the transition area between subpolar and subtropical gyres also contribute with multipolar anomalies at multiple frequencies: these tend to cancel one another in terms of the basin-wide air-sea CO2 flux [see NOCES publication *Raynaud et al.*, 2005].

- First accounting for time lag between interannual variability of air-sea CO2 fluxes and driving mechanisms [see NOCES publication *Raynaud et al.,* 2005]. Statistical analyses within NOCES have shown that there is indeed a strong correlation between air-sea CO2 fluxes and the North Atlantic Oscillation (NAO), but only if one takes into account time lags (maximum $r = 0.64$ for lags between 1 and 3 years) [see NOCES publication *Raynaud et al.*, 2005].
- Improved understanding of the effect of increasing atmospheric CO2 (the anthropogenic perturbation) on total variability. The effect is negligible at interannual time scales, whereas at the decadal (13-year) time scale, it increased variability by 30% [see NOCES publication *Raynaud et al.*, 2005].
- Serendipitous discovery that during preindustrial time there was probably a large ocean transport of about 0.8 $PgCyr^{-1}$ from the northern to the southern hemisphere, cause by iron limitated primary productivity in the Southern Ocean [see NOCES publication *Wetzel,* 2004]. This finding resolves a long-standing enigma as to why all other ocean models (none of which featured iron limitation) could not simulate such a large interhemispheric ocean transport, as theorized based on supposed preindustrial atmospheric CO2 gradients.
- Serendipitous discovery that high-latitude surface waters may become corrosive to CaCO3 minerals such as aragonite by the end of the century, a first in perhaps 25 million years [see NOCES publication *Orr et al.*, 2005]. This would seriously threaten marine calcifying organisms such as cold-water corals [*Guinotte et al.*, 2006] and some plankton.
- Production of various other related scientific publications from NOCES (see activity reports from each of the work packages).

Socio-economic relevance and policy implications

NOCES addressed how improving our understanding in the variability of the air-sea CO2 flux in the Northern Hemisphere would (1) reduce uncertainties concerning uptake of atmospheric carbon by the terrestrial biosphere and (2) improve predictions of future atmospheric CO2. Both concerns are relevant to EU environmental policies, and in particular the Kyoto Protocol, by which EU member states have agreed to reduce fossil carbon emissions.

The NOCES project built on the current EU investment in several recent of ongoing projects (e.g. CARBOEUROPE, CAVASSOO, PREDICATE) and has help set the stage for ocean, global carbon cycle and biogeochemistry research has started to be conducted during 6th Framework (CARBOOCEAN and EUROCEANS projects). NOCES was carried out at the European level, i.e., its goals could not have be obtained from any of the Members States alone because it required extensive model comparison and evaluation with a diverse group of models to provide interpretations that are not model specific.

Conclusions

Accomplishments during NOCES came more slowly than originally planned because it proved difficult to elaborate, refine, and agree on the many details necessary to make rigorous comparisons of model simulations of interannual variability. Nonetheless, the NOCES modelling groups persisted. Besides important scientific findings, NOCES has provided a protocol document and an archive of standard model output from multiple models, both of which will serve as de facto references for such simulations for years to come.

Keywords

CO2, air-sea CO2 flux, interannual variability, decadal variability, ocean, ocean models, carbon chemistry, biogeochemistry, oceanography, ocean circulation, ocean carbon cycle, global carbon cycle, ocean modelling, model comparison, intercomparison, model-data comparison.

Partners

N°	Organisation	Country
1	CEA-CNRS – Laboratoire des Sciences du Climat et de l'Environnement	France
2	Université de Versailles – Département de Physique	France
3	Met Office – Hadley Centre for Climate Prediction and Research, Berkshire	UK
4	Institut für Meereskunde, Department of Theory and Modelling, Kiel	Germany
5	Max Planck Institute for Biogeochemistry, Jena	Germany
6	Max Planck Institute for Meteorology, Hamburg	Germany
7	Université de Liège, Laboratory for Planetary and Atmospheric Physics	Belgium
8	Université Pierre et Marie Curie, Paris	France
9	Nansen Environmental and Remote Sensing Centre, Bergen	Norway
10	Sir Alister Hardy Foundation for Ocean Science, Plymouth	UK
11	University of East Anglia, Norwich	UK

POP - Pole Ocean Pole project

EVK2-2000-00089

http://www.esc.cam.ac.uk/pop/

Instrument:	FP5 Research Project	Contract starting date: 01/12/2000
Total project cost:	3.265.396 €	Duration: 42 months
EC Contribution:	1.773.968 €	
Organization:	University of Cambridge, Department of Earth Sciences, Cambridge, UK	
Co-ordinator:	Jenny Walsham (jrw46@admin.cam.ac.uk)	
EC Contact person:	Ib Troen (ib.troen@ec.europa.eu)	

Objectives

POP (Pole-Ocean-Pole) was proposed with the overarching objective of developing the methods for linking palaeoclimatic records from the polar ice cores and from deep ocean sediments. By examining sediments from the world oceans it is possible to make very valuable reconstructions of many aspects of the Earth climate system over the past million years and more. Methods for developing time scales for deep ocean sediment records have evolved over the past 30 years, largely based on work by Shackleton and colleagues in the 1970's. On the other hand the polar ice cores have certain unique advantages. First, they contain bubbles of "fossil" air so that the natural record of changes in greenhouse cases can be obtained. Second, they are capable of yielding a more detailed record (in the Greenland ice sheet even at annual resolution, in the deeper parts of the Antarctic ice sheets better than century resolution) than marine cores that can very rarely yield a resolution better than about 200 years. Third, the factors controlling variations in snow accumulation are easier to understand than those causing changes in the accumulation of marine sediment, so that the conversion from depth to geological age can be carried out in a more refined manner.

Unfortunately Greenland is only able to provide records covering about 110,000 years (one glacial cycle) but these records are of superb quality and provide an ideal template for understanding the details of climatic variability in the North Atlantic region over that time interval. At the time that POP was proposed, the Vostok record from Antarctica provided the longest record, about 400,000 years. Hence the focus of POP was to develop an accurate and precise age scale for the Vostok record and for marine cores that could be precisely linked to it. There was to be a special focus on those cores that could substitute for the Greenland ice sheet by yielding highly detailed climatic records for the North Atlantic region.

Scientific Achievements

For the last glacial cycle (the last seventy thousand years) POP developed a new age scale for ice cores in both the Greenland and Antarctic polar ice sheets as well as for marine sediments of the North Atlantic Ocean. This also permitted improved calibration of the radiocarbon time which assists in applying a consistent age scale to sedimentary records of rapid environmental change over this time interval in sediment cores from the other ocean basins and in records that are collected on the continents.

For the 400,000-year time interval that is covered by the Vostok ice core that was collected in central Antarctica POP developed a new age scale that has been applied to the three long cores from central Antarctica that have so far been collected: Vostok, Dome Fuji, and Dome C.

Significant advances were made within POP in obtaining a reliable age scale for the air bubbles that have been analysed within the ice cores, so that we also have a more reliable age scale for the history of natural variations in the concentration of greenhouse gases (carbon dioxide and methane) in the atmosphere.

Records of changing sea surface temperature, and of conditions on the sea floor bathed by the ocean deep water masses, were collected from the subantarctic Indian Ocean, the tropical Indian Ocean, and both the East and the West of the North Atlantic Ocean. These records are extremely detailed and can be linked to the ice cores with unprecedented reliability. This will permit a more detailed understanding of the relative timing of changes in different components of the global climate system.

New modelling in the POP project provides a considerably better understanding of the mechanism by which climatic changes propagate through the climate system with delays that can amount to over 1000 years.

Main Deliverables

The project has delivered new sediment cores, new analyses, new methodologies and new theoretical concepts.

A suite of cores from the North Atlantic off Portugal was collected. Many types of analysis have already been performed on these cores, but they remain as a legacy for future researchers

A very large number of oxygen isotope analyses; carbon isotope analyses; alkenone-based temperature estimates; fossil microfossil counts and other measurements have been collected. These will provide the basis both for publications by the POP scientists and by the broader community for whom these will constitute valuable data archives. Important new data, particularly regarding the concentration of methane in the air bubbles spanning the last 400,000 years, have been obtained.

Significant advances have been made in the methods for interpreting records in ice cores. In particular methods for estimating the air temperature actually associated with the bubbles that are subjected to analysis have been refined.

A new approach to the development of age scales in ice cores has led to a better understanding of the time frame for the records in these cores.

New model results have been published that advance our understanding of the operation of the so-called 'bipolar seesaw' whereby temperature changes in one hemisphere can lead to changes in the opposite sense in the opposing hemisphere.

Socio-economic relevance

The POP findings will help to refine the reliability of the atmospheric and coupled atmosphere-ocean models that are used to predict future trends in global climate that will result from the continuing addition of greenhouse gases to the atmosphere that mankind is causing.

Conclusions

A broad conclusion that may be drawn from the findings of the POP project is that the 'bipolar seesaw' concept does constitute both a valuable means for describing the past record of rapid natural climate variability, and a useful route to making testable predictions that will further consolidate our confidence in climate model predictions.

Keywords

Palaeoclimate, ice cores, deep-sea cores, alkenones, stable isotopes, methane, Vostok, North Atlantic, Greenland, Alboran Sea, Indian Ocean, Time-scale, Age model, millennial-scale variability, seesaw

Partners

N°	Organisation	Country
1	Centre National de la Recherche Scientifique, Saint-Martin-d'Hérès	France
2	University of Berne	Switzerland
3	Consejo Superior de Investigaciones Cientificas, Barcelona	Spain
4	Commissariat a L'énergie Atomique, Gif Sur Yvette	France
5	Centre National de la Recherche Scientifique, Gif Sur Yvette	France

QUOBI - Quantitative Understanding of Ozone losses by Bipolar Investigations

EVK2-2001-00129

http://www.nilu.no/quobi/

Instrument:	FP5 Research Project	Contract starting date: 01/01/2002
Total project cost:	2.883.725 €	Duration: 36 months
EC Contribution:	1.749.999 €	
Organization:	Alfred Wegener Institute for Polar and Marine Research, Potsdam, Germany	
Co-ordinator:	Peter von der Gathen (gathen@awi-potsdam.de)	
EC Contact person:	Claus Brüning (claus.bruening@ec.europa.eu)	

Objectives

- Determination of chemical ozone loss by two additional independent techniques, namely the tracer correlation approach and the vortex average approach.
- To investigate possible differences in the results of the methods, both among each other and with the Match results, thereby increasing the credibility of the deduced ozone loss.
- Providing models with Match ozone and trajectory data and ECMWF with real-time ozone sonde data for assimilation into its weather forecasting model.
- Intercomparison of models.
- Comparison of models with Match observations.

Scientific achievements

Models describing polar ozone loss have been significantly improved. The obvious discrepancies between observations and former model versions are largely resolved. A new set of kinetic parameters describing chlorine photochemistry was derived by the JPL from in situ ClO and Cl_2O_2 measurements made during the SOLVE/THESEO campaign in 1999/2000 and the SOLVEII/VINTERSOL campaign in 2002/03. It was shown that the Cl_2O_2 photolysis frequency must be increased if the updated description of the Cl_2O_2 production given by NASA/JPL [2003] is correct. In addition, the equilibrium constant describing the thermal decomposition of Cl_2O_2 has to be decreased to be consistent with night-time observations of ClO. Within QUOBI the impact of this new set of reaction constants has been tested, showing that the ozone loss in the models could be increased by up to 20% during twilight conditions, which decreases the gap between models and experiments. These box model results using the new set of kinetic parameters are significant as they show for the first time that, under the assumption of full chlorine activation, a chemical model can reproduce the large Match January ozone loss rates using 'accepted' chemistry.

Socio-economic relevance and policy implications

European countries and the European Union have responsibilities under the Montreal protocol and the Framework Convention on Climate Change. Knowledge about the state of the ozone layer constitutes the basis for negotiations and decisions on the political level concerning the phase-out of ozone depleting substances. There had been doubts that our understanding of the ozone loss is complete. It is EU policy to look for potential risks which can harm the environment and life on earth. Polar ozone losses can now be described in models better than before. In the future this should enable Coupled Climate Models (CCM) to predict the ozone layer of the coming decades better. New potential risks were not identified.

Conclusions

Models describing polar ozone loss have been significantly improved. The obvious discrepancies between observations and former model versions are largely resolved.

Keywords

Ozone, ozone loss, ozone depletion, ozone hole, stratosphere, Arctic, Antarctic, Montreal protocol, 3D model, trajectory model, box model, Match campaign.

Partners

N°	Organisation	Country
1	Alfred Wegener Institute for Polar and Marine Research, Potsdam	Germany
2	Central Aerological Observatory, Department of Atmospheric Compositions, Moscow	Russia
3	British Antarctic Survey, Cambridge	UK
4/5	Université Pierre et Marie Curie/Centre National de la Recherche Scientifique, Service d'Aéronomie, Paris	France
6	Danish Meteorological Institute, Research and Development Department, Copenhagen	Denmark
7	Finnish Meteorological Institute, Sektion of Ozone and UV Research, Helsinki	Finland
8	Free University of Berlin, Institut fuer Meteorologie - Fachbereich Geowissenschaften	Germany
9	Forschungszentrum Jülich, Institut fuer Chemie und Dynamic der Geosphaere	Germany
10	Instituto Nacional de Técnica Aerospacial, Observacion de la Tierra, Teledeteccion y Atmosfera, Madrid	Spain
11	Norwegian Institute for Air Research, Kjeller	Norway
12	University College of Wales, Department of Physics, Aberystwyth	UK
13	University of Cambridge, Department of Chemistry	UK
14	University of Leeds, School of the Environment	UK
15	Aristotle University of Thessaloniki, Laboratory of Atmospheric Physics	Greece
16	Natural Environment Research Council, British Antarctic Survey, Cambridge	UK

RAMAS - Radiometer for Atmospheric Measurements At Summit

EVK2-CT-2001-00097

http://www.ramas.uni-bremen.de/ramastext.html

Instrument:	FP5 Research Project	Contract starting date: 01/08/2001
Total project cost:	1.322.801 €	Duration: 41 months
EC Contribution:	1.322.801 €	
Organization:	University of Bremen, Inst of Environmental Physics, Bremen, Germany	
Co-ordinator:	Harry Küllmann (harry.kuellmann@iup.physik.uni-bremen.de)	
EC Contact person:	Claus Brüning (claus.bruening@ec.europa.eu)	

Objectives

Within the RAMAS project a new microwave sensor has been developed for deployment at the unique Arctic research station Summit (72 N, 38 W) in the interior of Greenland at an altitude of 3200 m. As microwave measurements are severely attenuated by tropospheric water vapour, high altitude stations like Summit are best suited for a microwave sensor. Equipped with a tuneable SIS receiver and local oscillator, it is possible to perform measurements in different observing bands within the frequency range of 265 – 282 GHz and collect data of different key trace gases (O_3, ClO, N_2O, HNO_3, HCN) nearly simultaneously. The bandwidth of the AOS of 2.0 GHz with a resolution of 1.1 MHz allows profile retrieval over an altitude range of 12 – 55 km. Summit is the only station in the Arctic suitable to operate such a sensor year round. Measurements obtained by RAMAS are required in long term monitoring programmes like the Network of the Detection of Stratospheric Change (NDSC), and also to test chemical and dynamical atmospheric models. Such models are needed to understand the complex processes in the Arctic stratosphere and to make predictions about the future changes of the Atmosphere driven by natural or anthropogenic effects.

Scientific achievements

Note: As outlined in the proposal in this first phase of the RAMAS project the instrument was designed, build moved to Summit and installed at Summit. Furthermore the instrument was tested and some preliminary observations were made. Therefore the actual scientific activities with RAMAS will start after, and during the next phase when the data will be validated and the operational phase begins. Therefore this section will concentrate on the more technical achievements.

Within the first year of the project, the instrument was designed and manufacturing of parts started. Long lead items had to be specified and ordered. A laboratory container to house the sensor and auxiliary equipment was purchased and modification work on the container started. Also the development of software to operate the sensor and to process and analyse the data was initiated. Partners 3 and 4 started to prepared strategies for validation and interpretation of the data.

During the second year of the project, the RAMAS instrument was assembled and tested by Partner 1 in Bremen, with the instrument first in the laboratory and later in the container. Modifications had to be made to some critical parts such as the Dewar in order to reach a temperature sufficiently low (approximately 4.7 K) to operate the SIS mixer. The tuning of the SIS mixer for different measurement frequencies was tested, and an automatic tuning algorithm has been integrated to the controlling software. Existing profile retrieval codes (ARTS/Qpack and MOLIERE) have been modified to make

them suitable to be used for RAMAS measurements. Eventually the RAMAS container was shipped to Summit at the end of the second year.

During the third and last project year, the RAMAS container was installed at Summit and connected to the power supply and data links. A liquid nitrogen generator was purchased for installation at Summit, funded by CNRS Bordeaux and the Regional Council of Aquitaine and installed at Summit. In a next step the receiver was assembled in the container and tested at a sub unit level and finally at the beginning of the winter season first test measurements were performed, frequently interrupted by necessary tests of the hardware and modifications to the operating software. Problems encountered during this time were the unreliable SIS mixer and some cross talk in the intermediate frequency chain. However spectral data for all target species, namely O_3, ClO, HNO_3, N_2O and HCN were collected. The controlling software has been thoroughly tested and adapted during the instrument test phase. Existing retrieval codes, namely ARTS/Qpack and MOLIERE used independently by the Partners 1 and 2, were modified for RAMAS specifications and used to retrieve trace gas profiles.

Model calculations using different a-priori profiles and measurements were performed and compared with the MOLIERE retrieval software, which was prepared for RAMAS data by Partner 2. A 3D model was developed and prepared for RAMAS measurements by Partner 3, consisting of a transport, aerosol and chemistry module and a module for backward trajectories from Summit. Interfaces for data validation were set up. Partner 4 defined main measurement objectives and priorities, and a sample 3D model output has been supplied to Partner 2. Model simulations have been performed up to July 2003, which will be continued and compared with RAMAS observations when available in the upcoming validation/operational phase.

After an appropriate validation and test phase, following the now completed construction and installing phases, RAMAS will become a key element provided by European scientists of the primary Arctic station in the Network for the Detection of Stratospheric Change (NDSC) and perform long-term measurements to monitor the Arctic stratosphere and in particular the ozone layer and its changes.

In order to advertise the RAMAS project and to make its data available to the user community, a project brochure has been published and distributed within the science community.

Socio-economic relevance and policy implications

Stratospheric change in general and ozone depletion in particular are problems of a global dimension, and will affect Europe as a whole, in particular since anthropogenic effects play a very large role in stratospheric ozone destruction, and dominate the measured large seasonal decrease in polar ozone. Reduced ozone will not only have a negative effect on the quality of life, health and safety of mankind but also affects climate. A major monitoring effort is needed in support of international agreements such as the *Kyoto Protocol,* the *Long-Range Transboundary Air Pollution convention,* and the *Montreal Protocol,* the later with respect to the stratospheric ozone layer. Ozone loss needs to be treated as a global problem and is therefore clearly also of European dimension. Reduced ozone over Europe is closely linked to chemical and dynamical processes in the Arctic, which need to be properly addressed.

Keywords

Microwave radiometry, Arctic ozone layer, Stratospheric Chemistry

Partners

N°	Organisation	Country
1	University of Bremen, Institute of Environmental Physics	Germany

2	University of Bordeaux, Bordeaux Observatory	France
3	Danish Meteorological Institute, Copenhagen	Denmark
4	University of Leeds, School of the Environment	UK
5	Naval Research Laboratory, Washington	USA

SAMMOA - Spring-to-Autumn measurements and modelling of ozone and active species

EVK2-CT-1999-00049

http://www.nilu.no/projects/sammoa/

Instrument:	FP5 Research Project	Contract starting date: 01/03/2000
Total project cost:	1.468.300 €	Duration: 24 months
EC Contribution:	999.300 €	
Organization:	Norwegian Institute for Air Research (NILU)	Kjeller, Norway
Co-ordinator:	Paal Berg (paal.berg@nilu.no)	
EC Contact person:	Georgios Amanatidis (georgios.amanatidis@ec.europa.eu)	

Objectives

The overall objectives of SAMMOA were to augment the existing observations of stratospheric ozone, and of species related to ozone chemistry, in the spring and summer high latitudes. The project aimed at bridging the gap that existed between current models of the ozone seasonal cycle and observations, focusing on the following main issues: (i) improve the overestimation of polar ozone in summer by current models, (ii) assess quantitatively the estimation of ozone loss in spring over mid-latitudes, and (iii) characterize the impact of the summertime Arctic ozone low upon mid-latitudes.

More specifically, the project aims were:

- Gather new observations in spring/summer 2000 and 2001 at three stations in the European sector of the Arctic. This involved ground-based observations of ozone and other trace species by means of ozone lidar and FTIR spectroscopy, as well as a series of balloon flights.
- Retrieve a three-dimensional ozone field from GOME satellite measurements for the period of spring/summer 1997 and 2000, assimilate the ozone profiles into a transport model, and validate the assimilated ozone against ozone sondes or other satellite data.
- Perform model simulations of ozone chemistry, as well as the transport of long-lived tracers for several spring and summer periods, using chemical transport models and Lagrangian trajectory models.
- The new observations, both ground-based and satellite, and the model studies are analysed with respect to ozone transport and chemistry. The main emphasis is understanding and modelling of ozone loss processes in spring and summer, the mixing of ozone and trace species during and after the breakdown of the polar vortex, and the formation of the summertime low-ozone over the Arctic, and its impact on mid-latitudes.

Scientific achievements

WP1:

- New lidar measurements of the ozone profile in the Arctic in summer, using a daylight system.
- Continuous column measurements of a series of trace species in spring and summer 2000 and 2001 in the Arctic.
- A new series of monthly balloon-borne in-situ CFC measurements were made from Kiruna, spanning a 6-month period in year 2000.

WP2 :

- A three-dimensional ozone field retrieved from satellite has been assimilated in a model through two spring and summer seasons. The ozone profiles were retrieved from GOME satellite observations for the spring and summer periods of 1997 and 2000. The processed ozone profiles have been validated by comparison to collocated measurements of ozone sondes and satellite observations. Biases are less than 10%. The GOME ozone profiles were assimilated using a Kalman-filter approach, which has proved to be a feasible approach for the large data set required for SAMMOA.
- Analysis of the GOME satellite ozone observations and detailed local comparisons with measurements at ground-based Arctic stations have allowed to quantify the near-steady decrease of ozone in the high latitudes in summer, as well as to reveal marked, low column ozone episodes.

WP3:

In the last decade massive ozone depletions inside the Arctic vortex have often taken place. It turns out that the vortex and its remnants have preferred locations (Europe and Russia), where the depletion they contain leads to an increase in the magnitude of the ozone trend. Longitudinal differences in ozone trends have been shown to arise from a combination of decadal variation in the circulation and dilution. This combination may account for a large fraction of the longitudinal trend variations. For mid-latitudes it explains 81 % of the variance, whereas only 35 % is explained if the vortex ozone depletions are not included. The part of the total mid-latitude trend in spring that may be attributed to vortex depletions is about 20 %.

- No trend is observed in the wave-driving of the northern hemisphere winter stratosphere, as has previously been suggested. This means that chemical ozone destruction is the main cause for the observed downward trend in ozone in spring.
- For the first time long-term 3D CTM simulations have been carried out to look at the observed ozone trends from 1979 to 1998 in the mid-latitude lower stratosphere. These simulations indicate that halogen chemistry is the main cause of the trend and dominates over any dynamically induced change. For the model halogen-induced ozone trend around 30-50% is due to the effects of polar chemistry and subsequent transport, with the balance due to 'in-situ' loss.
- Both observations and model results indicate that the chemical signatures found in vortex remnants display inter-annual variability, depending on the vortex break-up date. The ozone loss in remnants formed in mid-March 2000 are dominated by chlorine and bromine cycles, while this is not the case for the vortex remnants formed during the late break-up in May 1997. The mid-latitude ozone deficit in spring 2000 is dominated by dilution, and until mid-April, by chlorine and bromine ozone destruction within the vortex remnants.

WP4:

- Improvements have been brought to chemical transport models, allowing to significantly reduce the high summer column ozone bias at high latitudes (by about 50DU). The improvements relied on better treatment of seasonal ozone forcing and transport in the lowermost stratosphere, and on more accurate description of the nitrogen chemistry. A benchmark comparison of the CTM and the two Lagrangian models was carried out during the summer of the POLARIS campaign of 1997. The contribution to ozone loss by the various cycles was estimated. Through improvements in the nitrogen chemistry, the ozone destruction rate is enhanced by 3-5%.
- Long-lived vortex debris were identified in model simulations, well into summer, at altitudes above 20 km, while at lower altitudes the more intense mixing contributes to a more rapid mixdown of the vortex remnants. These were termed "fossil" remnants of the polar vortex.
- A comprehensive study of Arctic ozone variability in the summers 2000 and 2001 was realised. The Arctic low-ozone pool of air was seen to be greatly distorted and, on several occasions, was displaced toward mid-latitudes. These meridional excursions induced a slow variability on time

scales of several weeks that was clearly observed in sondes and lidar measurements in northern Europe.

WP5:

- A new technique has been developed to quantify isentropic mixing in different regions of the stratosphere, relying on the existence of separate "canonical" correlation curves describing air from the polar vortex, from the midlatitudes or the tropics. These curves merge into one upon the collapse of the polar vortex.
- High resolution simulation have been used to simulate the break-up of the polar vortex in the spring of 2000 and of 2001, allowing to identity long-lived vortex remnants. Correlation curves were compared in both models and observations.
- Whether stratospheric trace species' measurements can adequately reproduce these canonical correlations, was assessed by sampling a model according to various measurement platforms and strategies (e.g. balloon-borne, aircraft, or satellite). The results indicate that high-accuracy measurements at as few as two different locations are sufficient to capture the canonical correlations.

Socio-economic relevance and policy implications

- Atmospheric chemical models are under constant improvements. New developments in chemistry and transport models that lead to a more reliable prediction of future changes in stratospheric ozone layer, and support the regulatory strategies regarding stratospheric ozone trends, are valuable.
- Reduce ozone leads to increase in the UV radiation reaching the surface, which has an adverse effect on human health. Better understanding and modelling capability of ozone layer variability in spring and summer, when ozone layer thinning is maximum and UV exposure in mid-latitudes is highest, is therefore important. Impact of summertime low-ozone episodes associated with southward displacement of Arctic air on erythemal UV doses was demonstrated to be significant. Assessing the future UV climate over Europe in all seasons hence must rely on understanding and modelling the processes that lead to low ozone events.

UV radiation also affects chemical processes in the lower atmosphere, and hence impacts on the concentration of a large number of tropospheric compounds.

Conclusions

Through SAMMOA, there have been significant improvements in model estimations of ozone loss processes in summer and reductions in model ozone biases. The effect of ozone dilution over midlatitude ozone trend in the spring has been estimated in a quantitative manner.

For the first time, an ozone assimilation based on GOME observations and covering spring and summer periods was obtained. The time-evolving synoptic view provided by the data assimilation has allowed to reveal new features in the transport of ozone in the summer stratosphere, both at high and mid latitudes. A unique combination of new ground-based ozone profiling by means of lidar, and ozone data assimilation as well as Lagrangian model studies has allowed to show displacements of the pool of low-ozone Arctic air toward northern high latitudes. Particularly extreme low-ozone episodes in northern Europe, when the column ozone dropped significantly, were found to be reinforced by these meridional excursions of the upper-level, mid-stratospheric ozone-depleted air.

Finally, the project has allowed to continue into the springtime the detailed investigations of polar ozone loss carried during the winter 1999/2000 in the frame of the international THESEO2000-SOLVE campaign. This has resulted in three publications in special issues of scientific journals devoted to this

campaign. The new data collected during SAMMOA campaigns of summer 2000 and 2001 will without doubt continue to be exploited over the next years.

Keywords

Stratospheric ozone, chemical transport models, Arctic research, polar ozone, Montreal protocol

Partners

N°	Organisation	Country
1	Norwegian Institute for Air Research (NILU)	Norway
2	Danish Meteorological Institute	Denmark
3	University of Oxford	UK
4	University of Leeds, Environment Centre	UK
5	Forschungszentrum Jülich GmbH	Germany
6	Alfred-Wegener Institute, Potsdam	Germany
7	Royal Netherlands Meteorological Institute	Netherlands
8	The University of Cambridge	UK
9	Swedish Institute of Space Physics	Sweden

SCANNET - Scandinavian/North European Network of Terrestrial Field Bases

EVK2-CT-2000-20007

http://www.scannet.nu

Instrument:	FP5 Thematic Networks (TN)	Contract starting date: 01/02/2001
Total project cost:	775.165 €	Duration: 36 months
EC Contribution:	775.165 €	
Organization:	Royal Swedish Academy of Sciences	Stockholm, Sweden
Co-ordinator:	Terry V. Callaghan (t.v.callaghan@sheffield.ac.uk)	
EC Contact person:	Riccardo Casale (riccardo.casale@ec.europa.eu)	

Executive summary

SCANNET is an expanding network of field site leaders, research station managers and user groups in northern Scandinavia and Europe that are collaborating to improve comparable observations and access to information on environmental change in the North Atlantic Region. The SCANNET consortium now consists of 14 partners that represent large geographical gradients in environmental conditions and land use throughout the North Atlantic Region while data series at many of the sites within the network provide estimates of variability over long periods of time. SCANNET partners hold environmental data sets, provide stability for research and facilitate long term observations in terrestrial and freshwater systems. Together, they host most of the EU funded projects with a northern terrestrial dimension.

SCANNET is set within the context of major environmental and land use changes in the North and is as relevant today as it was at its inception. Globalisation of economy, markets and policies, impacts of climate change, trans-boundary pollution, subsidiarity, changes in land-use and other issues increasingly influence Northern terrestrial ecosystems and quality of life. Biodiversity, environmental quality and ecosystem function are under threat in these cold-dominated areas which represent the largest, relatively undisturbed, 'wilderness' of Europe. Changes within the region also have significant effects on conservation and resource use in lower, temperate latitudes.

The overall objective for SCANNET has been to establish a network, which facilitates comparative and regional environmental science activities aimed at addressing questions of variation in system sensitivity and response to environmental change. Central aims of the project have been to strengthen the capacity of field Stations to store and access data and information for their own use; to enhance cross-site compatibility and exchange of data and information and to provide data and information to organisations concerned with national, regional and global policy.

SCANNET's output is benefiting six main groups of users at three geographical scales: local, regional and global. The main user groups are local communities, larger organisations, scientists, and international organisations. SCANNET is contributing to the need for more integrated monitoring in the North-Atlantic region and improving the provision of data from Europe to regional and global observing systems. Despite the imminent end of the EU contract, it is continuing to strengthening the regional infrastructure that is required to exploit existing data and observations of the effects of changes in climate and land use by operating an expanding network of field sites, linking to other relevant networks, and by generating an accessible meta-database and database.

SCANNET is using a range of methodologies. In order to provide clearer focus for the tasks of compiling site data and of stimulating cross-Station understanding, individual partners have taken the lead on particular subjects in which they have special expertise. There were five Work packages (XPs) dealing with data on climate variability, climate scenarios, variability in biodiversity, variability in species performance and variability in human dimensions. Some of these work packages adopted an ideal structure that involves infrastructure manager, researcher (science user) and expert consultant.

The administrative matrix to cement SCANNET into a fully functional network is being provided by a Secretariat that ensures information flow among SCANNET partners and between SCANNET and the wider user community. Newsletters are regularly produced but a web site is our main method of making data more accessible. It includes a wide range of information including details of the Stations' infrastructures, research emphases, environmental and land use envelopes and databases with Internet interfaces, including searchable bibliographies of research outputs. The development of meta-databases and databases has continued and all the final work package reports have been published on the SCANNET web site.

During the three years SCANNET has complete all its deliverables. The SCANNET network continues to be fully functional and it is expanding. All targets have been achieved and slight delays in a few work packages did not have any adverse impact while their justified extension has enabled more comprehensive reports to be achieved.

SCANNET has developed beyond what was originally planned and its achievements represent full and enthusiastic collaboration among all partners that has lead to the signing of a "Memorandum of Understanding" aimed at continued collaboration among facilities. Beyond this, even at the final stage of the EU contract, SCANNET has been approached by an additional 10 sites that wish to join and a second Memorandum of Understanding has been signed by SCANNET and five of these sites. SCANNET has also been requested to represent the North Atlantic Region in a new circum-arctic environmental programme that is being submitted to the Arctic Council of Ministers for approval.

SCANNET now provides a one "stop-shop" for environmental information on the North Atlantic landmasses. The meta data bases of environmental monitoring activities, the site specific conditions in the North Atlantic Region, the searchable bibliographies of research at the sites, the data bases and the compilations and summaries of data submitted in final reports together provide highly accessible information. Not only has access to existing but previously widely distributed data been improved, but some previously unavailable data have been made available. Such information now available can facilitate general overviews of the environments in the North Atlantic Region as well as in dept studies, for example the frequency of extreme climatic events.

SCANNET and its research user group has published a summary of the varied environmental condition in the north of Europe together with current and projected environmental changes there. Drawing on a range of expert judgement, local knowledge, research and hitherto obscure publications, the study demonstrates some of the potential of SCANNET together with its research user group.

The North Atlantic Region has a highly variable environment that is potentially sensitive to change. SCANNET has provided an invaluable compilation of data and metadata about the North Atlantic Region which has been brought into one location, the SCANNET web site. This will provide a platform of growing information for future assessments of environmental change and their impacts as well as infrastructure platforms to facilitate research and international campaigns. SCANNET has gained international recognition and partnership with SCANNET is being sought by other networks from Europe and beyond.

Partners

N°	Organisation	Country
1	Royal Swedish Academy of Sciences, Stockholm	Sweden
2	Norwegian Polar Institute of the Ministry of Environment, Tromsoe	Norway
3	University of Turku	Finland
4	Natural Environmental Research Council, Swindon	UK
5	Norwegian Institute for Water, Oslo	Norway
6	Danish Polar Center, Copenhagen	Denmark
7	University of Helsinki	Finland
8	Icelandic Institute of Natural History, Reykjavik	Iceland
9	Faroe Islands Geology Museum, Hoyvik	Faroe Islands

SIBERIA II – Multi-Sensor Concepts for Greenhouse Gas Accounting of Northern Eurasia

EVG1-CT-2001-00048

http://www.siberia2.uni-jena.de

Instrument:	FP5 Research Project	Contract starting date: 01/01/2002
Total project cost:	4.293.410 €	Duration: 42 months
EC Contribution:	2.731.331 €	
Organization:	Friedrich-Schiller-University Jena	Jena, Germany
Co-ordinator:	Christiane Schmullius (c.schmullius@geogr.uni-jena.de)	
EC Contact person:	Claus Brüning (Claus.Bruening@ec.europa.eu)	

Objectives

The main objectives of the EC-project SIBERIA-II are the integration and combination of multisensor remotely sensed data and ecological regional models in order to assess the impact of terrestrial biota on the budget of major greenhouse gases (GHGs) in Northern Eurasia and the demonstration of the viability of full carbon accounting (including CO2, CO, CH4, N2O, NOx) using Dynamic Vegetation Models (DVMs) and multi-sensor Earth Observation (EO) instruments.

The tools and systems to be employed include a spectrally and temporally diverse set of multisensor Earth Observation instruments and detailed existing databases of field information and vegetation models to account for fluxes between land and atmosphere. The prime use for the EO products within this project is to drive and to validate models for C and GHG assessment in the SIBERIA-II test area. Two biosphere process models (Lund-Potsdam-Jena, i.e. LPJ-DVM and Sheffield-DVM) and one landscape-based regional model are used in the project.

Scientific achievements

During the first year of the project the thematic, spatial and temporal requirements for EO-retrieved greenhouse gas accounting parameters have been determined. In the second year, major objectives concerned the methodological development for the implementation of these parameters into the accounting models, further establishment of the data archives, the operational production chain for the parameters, and a first design of the validation strategy.

During the third year, EO products have started to be used in the GHG accounting and the DGVM approaches. With these applications, SIBERIA-II is proceeding to frontier science results about implementing EO with global change tools for an integrated Earth System Science analysis. The 3rd project year finalized very successfully in a dedicated SIBERIA-II project session at ESA's ENVISAT Symposium in Salzburg, 6-10 September 2004, with ten partners presenting their results.

Experiences from the 2nd project year supported the initial hypotheses on the need for a multidimensional approach, which can compensate the shortcomings of some information sources while benefiting from their strengths. The models and algorithms that have been developed and preliminary results indicate that significant decrease of uncertainty in the GHG accounting can only be provided by an appropriate fusion of EO products, ground data and models of different types. Exploitation of EO data in the DVMs has been prioritised by what is feasible and what is likely to be most important. Hence substantial effort has been spent in making best use of the land cover products, together with phenology

information, and we are continuing with efforts to use the snow data (hopefully in concert with freeze-thaw data). Exploitation of APAR data would in principle be possible, at least for comparison with the models, but it is likely that there is not enough time or resources are available to carry this through in any substantial way.

Similarly it is not clear how to use the fire data within the structure of the DGVMs, although the ecosystem-landscape approach offers a more natural route to use of these data. The key communal activity, involving SCEOS, PIK and IIASA, in the remainder of the project is to carry out a concerted comparison of the three approaches to estimating the Siberian carbon budget, and, in consultation with CEH, to provide estimates of the uncertainties in these calculations, where this is possible.

The programme to carry out a concerted comparison of approaches and further uncertainty analysis has been defined and will provide some of the key outputs of the project over the remaining project lifetime.

Socio-economic relevance and policy implications

The ability to independently derive land surface information from EO data is of critical importance to European organisations. This is demonstrated by the ability of the SIBERIA-II team to derive freeze/thaw, wetlands, phenology, biomass, snow depth, forest fires and ARD, at a regional to continental scale from a large range of EO data, or to refine existing products such as land cover to meet the project requirements.

In the framework of the landscape-ecosystem approach, use of satellites is irreplaceable in at least three aspects: (1) for identifying current land cover, (2) for delivering the seasonal course of environmental indicators, particularly in vast, remote areas lacking any meteorological measurements, and (3) for identifying natural and human-induced disturbances. Coupled with results from DVMs, this allows development of methods and technologies for full GHG accounting that will be relevant for post-Kyoto international negotiation processes. Simultaneously, the approach presents operative and reliable information for integrated land management, in particular for organizing an adaptive system of forest protection under acceleration of disturbance regimes in the project area. Finally, the approach provides unique data for estimating possible synergy in the use of diverse information sources.

The DVMs provide a means to project the current estimates based on the GIS approach into the future, and hence into policy based on adaptation and mitigation. Comparison with the GIS results and with EO measurements is important for testing the credibility of the model calculations and increasing confidence in the use of such predictions by policy-makers. In addition, using data to constrain DVM calculations increases confidence in their outputs and hence relevance to policy.

The GIS-GHG accounting presents comprehensive characteristics of vegetation, land-use and landcover, anthropogenic impact, disturbances, etc., thus generating unique information for managers of this large and insufficiently known region in Northern Eurasia. For instance, judgements on the transition to sustainable forest management are impossible without such information. Some results, which were received in 2002 and 2003, can be used in various climate change national and international studies and in Russian forest/land management: (1) the models of biological production for major forest forming species, which were presented for approval to the Russian Ministry of Natural Resources as official reference data for forest management purposes are considered as a comprehensive part of the project's results; and (2) databases of field measurements of different indicators of biological production, which are mostly unavailable elsewhere. In November 2004, Russia ratified the Kyoto Protocol. Results of the full GHG accounting have substantial importance for European countries with respect to the future implementation of the Kyoto Protocol in Russia. The information accumulated by SIBERIA-II as well as the methodological findings and modelling developments can be substantially used by the European Union in all three mechanisms recommended by the Kyoto Protocol.

Conclusions

SIBERIA-II results have gained increasing interest due to Russia's recent commitment to the Kyoto Protocol. ESA has published project results in this context on their webpage. SIBERIA-II results have also been promoted through the coordinator's role in the international GOFC-GOLD and NASA's NEESPI programmes, as well as through ESA's Land Cover Project Office at the coordinator's organisation.

The information accumulated by the project as well as methodological and modelling findings of SIBERIA-II can be substantially used by the European Commission e.g. in GEO and GMES plans, and by the European Union e.g. for the Kyoto Protocol. Overall, SIBERIA-II's progress and international recognition is beyond expectations due to an excellent, dedicated partnership, a good project timeline, and a challenging and innovative project goal.

Keywords

EO, Remote Sensing Synergy, FGHGA, GHG, GIS, Dynamic Vegetation Models, Land cover, Global Climate Change, Disturbances, Climate, Carbon Cycle, CO2, Kyoto Protocol, ARD.

Partners

N°	Organisation	Country
1	Friedrich-Schiller-Universität Jena	Germany
2	University of Wales Swansea	UK
3	Potsdam Institute for Climate Impact Research	Germany
4	Gamma Remote Sensing Research and Consulting AG, Bern	Switzerland
5	German Aerospace Centre, Köln	Germany
6	Université Paul Sabatier de Toulouse III	France
7	Vienna University of Technology	Austria
8	V.N. Sukachev Institute of Forest – Russian Academy of Sciences	Russia
9	Research Centre for Space Information Systems and Observation Technologies, Moscow	Russia
10	International Institute for Applied System Analysis, Laxenburg	Austria
11	University of Sheffield	UK
12	Irkutsk Committee on Natural	Russia
13	Dokuchaev Soil Institute, Moscow	Russia
14	Natural Environment Research Council, Banchory	UK

SITHOS - Sea Ice Thickness Observation System

EVK2-CT-2002-00146

http://www.nersc.no/Projects/SITHOS/

Instrument:	FP5 Research Project	Contract starting date: 01/12/2002
Total project cost:	3.039.321 €	Duration: 36 months
EC Contribution:	1.948.350 €	
Organization:	Nansen Environmental and Remote Sensing Center, Bergen, Norway	
Co-ordinator:	Stein Sandven (Stein@nersc.no)	
EC Contact person:	Riccardo Casale (riccardo.casale@ec.europa.eu)	

Executive Summary

The focus of the SITHOS project has been to develop and test new observing systems for sea ice thickness and related parameters for climate change detection, support to sea transport, offshore operations as well as environmental monitoring in polar regions. The project has collected and analysed new data sea ice sets from several field experiments, analyzed satellite altimeter data and conducted model simulations of sea ice in the Arctic. Sea-ice thickness is one of the most difficult ice parameters to measure, because it requires use of platforms which can operate in the ice environment. Today, most data have been gathered by upward-looking sonar measurements from military nuclear submarines. These data are normally released only years after they had been acquired, and with a poor geographic reference. Cruise tracks are designed for military interests, and not for scientific purposes. After the end of the cold war, even scientifically motivated cruises like the Scientific Ice Expeditions SCICEX will be performed only sporadically. Echo sounders deployed on oceanographic moorings can monitor ice thickness only at fixed locations. To obtain synoptic measurements of ice thickness is a real challenge, and several observing methods including use of satellites are required.

In the SITHOS project the following methods have been used:

- **use of electromagnetic induction** and laser (EM) mounted on helicopters which can operate up to 100 km from an icebreaker.
- **aircraft surveys with laser and GPS**. Scanning laser and GPS positioning can provide data on surface topography, freeboard and thickness from aircraft over distances from a few hundred to thousand km depending on type of aircraft (AL)
- **use of Upward Looking Sonars (from submarines and AUVs)** for mapping of ice draft along tracks (ULS)
- time series of ice thickness from **automatic ice stations** (AIS) deployed on ice floes in the interior of the Arctic
- **satellite altimeter** data providing regular data on ice freeboard and thickness averaged to typically100 by 100 km grid cells
- **sea ice modelling** for comparison with the new data sets and validation of the modelled ice thickness and other sea ice parameters.

Use of electromagnetic induction (EM method) has become a well-established technique for measuring ice thickness. The method has been validated by in situ drilling during many field experiments before and during SITHOS. In SITHOS AWI has used a standalone system consisting of the EM device in combination with a laser, which is tailored to be operated from helicopters. Large data sets representative for certain ice regimes have been gathered. The comparison with in situ drilling shows very good agreement, except for the thickest ridges and ice keels, where the EM method tends to

underestimate the thickness. In a series of field experiments from 1991 to 2004, AWI has found the mean modal ice thickness in the European sector of the Arctic to decrease from 2.5 m to about 2.0 m for the summer period. For the winter period there are not any repeated measurements of ice thickness by this method.

Aircraft laser scanning and GPS surveys (the AL method) have been conducted by KMS during several of the SITHOS experiments. The basic idea is to use kinematic GPS in combination with laser to map the surface of the ice at few cm accuracy over longer distances which includes variations of geoide and sea surface topography. The height difference between geoid and laser/GPS is sea-surface topography plus ice freeboard. Through the SITHOS flight campaigns it has been demonstrated that the airborne lidar measurements are an effective way to measure sea ice thickness and freeboard over large scales (100 to 1000 km). Comparison with simultaneous EM measurements shows that the mean ice thickness measurements from the laser data are within 10 – 20 % of the EM data over 100 km distances. The method requires input data on ice and snow density in order to retrieve thickness from freeboard. In future sea ice observing systems it is recommended to use airborne scanning laser surveys, representing an important "bridging" of sea ice scales between locally based ground- and helicopter work and the large-scale coverage by satellites and occasional basin-wide surveys by submarines and icebreakers.

An interesting technique to drive spatially averaged ice thickness has been demonstrated using directional surface elastic-gravity wave measurements from Russian *North Pole* drifting stations. Measurements of ice surface oscillations were carried out regularly in the Eurasian Basin from 1972-91. The ice thickness obtained varied between 3.02 m and 2.8 m. In SITHOS two types of wave measurement buoys (Automatic Ice Station - AIS) have been developed and tested by SAMS and CMR/NERSC. The wave data collection is in progress and continues after the end of the SITHOS contract. The wave spectra derived from the buoys so far have been analysed, but retrieval of ice thickness has not yet been obtained. It is therefore too early to validate ice thickness retrieval by the wave method. The plan is deploy a cluster of AIS's which can measure wave spectra and retrieve ice thickness over the whole Arctic. This plan is included in the DAMOCLES project for 2006 – 2009. Autonomous Underwater Vehicles (AUV) which are small unmanned submarines operated from a ship, have been developed in recent years as part of the offshore technology.

In SITHOS one successful experiment was conducted in the Fram Strait where an AUV equipped with an upward-looking multibeam bathymetric mapping system measured ice draft along sections, each were a few tens km long. The system, which was called Autosub, operated highly successfully under sea ice, obtaining 458 km of high quality upward looking swath sonar data and accompanying oceanographic data. It undertook necessary avoidance manoeuvres for obstacles, and the acoustic homing system ensured that the vehicle could be returned with confidence to an area covered with loose moving pack ice. The combination of an unmanned under-ice vehicle and a multibeam sonar gives, literally, a new dimension to under-ice studies, and is important for work on ice thickness changes, the disappearance of deep ridges from the Arctic, navigability in ice, and many other studies critical to the role of ice in polar climate change.

It is hoped that this successful ice profiling mission will be a precursor to larger-scale missions with AUVs which will develop into a major monitoring effort for Arctic sea ice changes. Also ice thickness results from future AUV runs can be used to validate freeboard estimates from the satellite altimeters, in order to allow mean ice thickness to be estimated throughout the Arctic. The AUV has many advantages, notably the high resolution which is possible by sailing close to the ice bottom, a possibility which manned submarines cannot enjoy for safety reasons; and the possibility of a closely controlled tight or overlapping grid of imaging tracks. The main drawback of the present AUV is lack of range when compared to nuclear submarines.

Satellite radar altimetry has a potential to provide estimates of sea ice thickness for the whole Arctic area from direct measurement of ice freeboard. Preliminary results from the ERS radar altimeter show good agreement with in-situ submarine observations and reveal that Arctic ice thickness is highly variable and largely controlled by the length of the summer melt season [Laxon, et al., 2003]. Since September 2003 CPOM has been developing a processing system to extract sea ice thickness from Envisat altimetry data. The system can now produce ice freeboard and thickness maps within a short time after reception of the satellite data. The result of the work has been to produce monthly ice freeboard maps for the winter seasons 2002-03, 2003-04 and 2004-05. The freeboard data have been averaged to 1 deg latitude and 5 deg longitude cells. The maps shows characteristic maximum freeboard in the Canadian archipelago where the thickest ice in the Arctic is found. The in situ data from the SITHOS field experiments have too small scale to be useful for validation of the altimeter maps. Other large-scale validation data for the altimeter results are not available.

The failure of the Cryosat launch in October 2005 has increased the importance of the Envisat altimeter for monitoring sea ice thickness, and work will continue to try to improve on the current results. One of the highest priorities is to improve the performance of the retracking algorithms.

The waveforms should be properly corrected for the antenna response to remove the bias in the observed floe elevations. The tracking of the sea surface in leads is believed to be working well, but work is planned on developing a retracker specifically designed for this purpose which could make use of a larger number of the specular returns than can currently be used. Hand in hand with this, further work is planned on more accurately separating leads from floes and data filtering by looking at satellite imagery. Finally, further validation with in situ data is highly desirable.

Sea ice modelling work has been conducted by NERSC and AWI to support the observational work from the field expeditions. The main purpose of demonstrating sea ice modelling results is to compare observed ice thickness by the different methods used in the other SITHOS tasks with modelled ice fields. The observations can be used to validate the model results, but the validation is of limited value when the observations are on a different scale compared to the models. The comparison can also be used to define scales of observations that are needed in the future for model validation. The AWI modelling activities show interesting results of ridge simulations and ice age simulations. This is complementary to the results provided by the NERSC models. The modelling systems are producing large-scale sea ice thickness fields which need to be validated on similar scales. This is a real challenge because most ice thickness measurements are obtained on regional and local scale. The large-scale observations by radar altimetry provide interesting data for comparison with large-scale model results. In this case the scale of observations matches the scale of the models. But the radar altimeter method needs further validation before it can be a useful tool for model validation. Another limitation is that sea ice models can only be expected to be as good as the atmospheric forcing fields and the ocean models coupled to the ice models. It is therefore important to provide improved atmospheric fields in the Arctic where the meteorological observation network is sparse.

The main achievements in SITHOS have been the field experiments where several methods of observing ice thickness have been successfully used to collect observations of ice thickness and related parameters. These methods have clearly complementary roles and should be used regularly in future observing systems. The main problem of most observing systems is that they cover local and regional scale, while for climate studies it is necessary to obtain data for the whole Arctic. Satellites have the capability to observe thickness on large scale and should be implemented as part of a global observing system with support from aircraft and in situ measurements.

Partners

N°	Organisation	Country
1	Nansen Environmental and Remote Sensing Center, Beren	Norway
2	Alfred Wegener Institute for Polar and Marine Research, Bremerhaven	Germany
3	Scottish Association for Marine Science	UK
4	University College London	UK
5	Christian Michelsen Research A/S, Bergen	Norway
6	KMS (National Survey and Cadastre), Copenhagen	Denmark

SPICE - Space borne measurements of Arctic Glaciers and implications for Sea Level

EVK2-2001-00262

http://www.geo.uio.no/geogr/spice/index.php

Instrument:	FP5 Research Project	Contract starting date: 01/11/2002
Total project cost:	1.049.881 €	Duration: 36 months
EC Contribution:	1.049.881€	
Organization:	University of Oslo, Dept. of Geosciences	Oslo, Norway
Co-ordinator:	Jon Ove Hagen (j.o.m.hagen@geografi.uio.no)	
EC Contact person:	Georgios Amanatidis (georgios.amanatidis@ec.europa.eu)	

Objectives

The main objectives of SPICE are to verify retrieval algorithms of satellite-derived glacier products using in situ measurements. The obtained knowledge will significantly contribute to the development of a method that combines different satellite data to obtain detailed information on the mass budget of arctic ice caps. In addition to the continuation of in situ measurements the project is devoted to assessing the state of balance of Arctic ice caps by integrating the achieved data and methods developed.

Scientific achievements

WP 1: Topography and elevation changes

Extensive datasets on surface elevation of Arctic glaciers were collected. These data serve partly as baseline reference for future surveys and partly to assess elevation changes where such reference data was available. As such, elevation changes of the Austfonna ice cap were determined using different datasets. The results suggest an increase in surface elevation in some parts of Austfonna, but the magnitude of the change is estimated differently by different methods. This finding has important implications for the sign of the contribution of large Eurasian Arctic ice caps to sea-level change in a future environment where sea-ice cover is expected to decrease; that is, sea-ice thinning and melting in a warming Arctic may result in ice-cap *thickening*, at least in the short term, due to increased precipitation.

WP 2: Dynamics of Arctic Ice Caps

Using a variety of methods, data on ice velocity, ice thickness and front position changes were collected in all target regions. The calving flux was assessed for two ice caps, and in both cases, the calving flux accounts for about 35-45% of the total mass loss, the remainder being surface runoff. The implication is that iceberg calving is responsible for a significant and quantifiable proportion of total mass loss from large ice caps located across the Arctic. Extensive datasets of ice thickness and surface elevation were also collected in the Kangerlussuaq region of the Greenland ice sheet and on the Vatnajökull ice cap. These data serve as necessary input to dynamic models of glacier response to climate changes.

Any further velocity data collected, either measured in situ or remotely sensed, is valuable validation data to control the performance of ongoing and future ice dynamical modelling.

WP 3. Glacier Facies and Albedo

Detailed ground measurements of snow reflectance anisotropy in conjunction to numerical simulations increased the present understanding of the interrelationship between snow characteristics and reflectance.

Further, satellite albedo products were validated in-situ. This study revealed considerable confidence in the reliability of the satellite product and its application. Satellite radiometer measurements were used to estimate summer meltwater production on the Devon Ice Cap. The results suggest that the average 1988-2002 meltwater production was about 3 $km^3 a^{-1}$.

WP 4: Field validation

A total of more than 15 AWS were operated on the ice caps of Austfonna and Vatnajökull, along the K-transect in Greenland and in the Kongsvegen area. The datasets collected by these AWS are essential input to drive mass balance models which were applied in WP 5.

Long term monitoring of glacier mass balance e.g., on Vatnajökull or along the K-transect in Greenland was continued. These datasets are of inestimable value for reconstructing climatic changes in the Arctic over the past decades.

A snow accumulation distribution pattern was developed and validated using GPR data, collected along several profiles across the Austfonna ice cap.

WP 5: Synthesis and modelling

One method estimates mass balance directly from satellite data. This approach was applied successfully on a number of glaciers and its limitations were investigated carefully. The advantage of this method is that summer mass balance of large regions can be assessed from satellite images by involving only a minimum of ground data.

Further modelling studies of the mass balance used satellite data as valuable control information when validating model performance. This modelling work represents a diagnostic approach to determine the current state of balance. When using projected data from GCMs, the sensitivity glacier mass balance to climate change could be assessed.

Main deliverables

During the SPICE project, the following deliverables were produced:

- Measurements of ice cap surface topography using airborne laser altimetry as well as ground based differential GPS survey to calculate elevation change through time.
- Calculation of surface elevation changes through comparison with former data.
- Assessment of implications for mass balance of Arctic ice caps.
- Measurements of glacier surface velocity using satellite images as well as in-situ surveying of stakes.
- Mapping of ice-thickness distribution in a drainage basin of the Greenland Ice Sheet.
- Derive data on advance and retreat of tidewater margins of Arctic ice caps.
- Calculation of ice mass fluxes and ice berg calving losses.
- Measurements and modelling of snow BRDF to develop useful parameterizations.
- Retrieval of glacier facies and albedo from satellite images and using in-situ data for independent validation.
- Maintenance and operation of automatic weather stations on a number of Arctic glaciers to record energy balance components that are involved in glacier melt.

- Field measurements of glacier mass balance components
- Continuation of existing long time series of glacier mass balance (e.g., Vatnajökull and K-transect in Greenland).
- Melt-rate distribution and total melt in the Kangerlussuaq drainage basin.
- Modelling mass balance of a number of Arctic glaciers using meteorological data as input and measured mass balance as control data to evaluate the model performance.
- Development and evaluation of methods to derive glacier mass balance from satellite-products.

Socio-economic relevance and policy implications

General Circulation Models predict that the Arctic will be the area that will warm most quickly during the 21st Century. The stability of the entire ecosystem of the Arctic and hence the basis for its inhabitants, depends crucially on temperature. Therefore, the Arctic will be affected severely by climate change. It is of crucial importance to assess the mass balance of the very large areas of glacier ice in the Arctic, because ice mass losses due to melting will cause global sea-level rise, which could reach about 0.5 m by the year 2100. About 50 % of the rise could be caused by Arctic glaciers shrinkage.

This is also a politically-acknowledged environmental hazard to Europe. Sea-level rise is of direct economic interest to all European countries with low-lying areas. Harbors are likely to be affected, as well as low-lying agricultural land and coastal communities. There are considerable costs of sea-defense strengthening in most European countries. Hence, design and predictions of the life time of such structures will be aided by an enhanced understanding of the contribution of glaciers to sea-level rise in a warming world.

A large part of the Arctic glaciers is located in remote areas which are difficult to access and are therefore not observed on a regular basis. Little is known about the behaviour of these ice caps which are especially vulnerably to climate changes and from which the major contribution to the sea level rise during the 21rst century is expected. Satellite remote sensing is a valuable tool to collect data over large and remote areas. The development of techniques to assess arctic glacier mass balance using satellite images is a most welcome contribution to the assessment of a major environmental change.

Conclusions

In this project, ongoing changes of Arctic glaciers were assessed using a range of different methods. In particular, new methods involving remotely sensed data were developed and their limitations carefully investigated.

The arctic glaciers and ice caps are irregularly distributed in space and are located in very different climatic regimes, from maritime climate to very continental climate; the morphology of arctic glaciers also shows a great variety. Thus, different responses to climate change must be expected. Most modelling in the present report is diagnostic, i.e. assesses the current mass balance for a static glacier geometry. With the exception of some recent work on ice caps in the Russian Arctic, a dynamic response of the glaciers is not taken into account. There is considerable uncertainty about how warmer climate may affect the dynamics of the glaciers since several feedback mechanisms may be involved. In future research the potential dynamic effects should be considered. This task will be addressed in coming projects for instance linked to IPY, e.g. GLACIODYN. Field investigations on selected key glaciers will be important in combination with new remote sensing data (CryoSat, Ice Sat) giving input to new modelling approaches which take also the dynamics into account.

Dissemination of results

The research conducted in this project is mostly fundamental research and of less applied character. Therefore, dissemination of results took place mainly in form of scientific publications and presentation to the scientific community at conferences and workshops. One international conference on Arctic glaciology was organized and held in Norway, August 2004.

Keywords

Climate change, glacier mass balance, arctic glacier, glacier retreat, sea level rise, remote sensing

Partners

N°	Organisation	Country
1	University of Oslo, Dept. of Geosciences	Norway
2	Utrecht University, Institute for Marine and Atmospheric Research	Netherlands
3	University of Iceland, Science Institute, Reykjavik	Iceland
4	University of Cambridge, Scott Polar Research Institute & Department of Geography	UK
5	Technical University of Denmark, Danish Center for Remote Sensing, Electromagnetic Systems, Lyngby	Denmark
6	National Survey and Cadastre, Department Of Geodynamics, Copenhagen	Denmark

TCOS-Siberia – Terrestrial Carbon Observing System – Siberia

EVK2-CT-2001-00131

http://www.bgc-jena.mpg.de/public/carboeur/web_TCOS/

Instrument:	FP5 Research Project	Contract starting date: 01/01/2002
Total project cost:	3.107.751 €	Duration: 48 months
EC Contribution:	2.824.636 €	
Organization:	Max-Planck-Institut für Biogeochemistry	Jena, Germany
Co-ordinator:	Martin Heimann (martin.heimann@bgc-jena.mpg.de)	
EC Contact person:	Claus Brüning (Claus.Bruening@ec.europa.eu)	

Summary

Terrestrial Carbon Observing System–Siberia, TCOS, includes an implementation of the first components of a continental scale observing system for an evaluation of the net Siberian carbon balance and its variation from year to year. This goal is addressed by means of an integrated top-down and bottom-up approach consisting of:

- Continuous surface flux measurements of CO2 in key ecosystems at 4 locations.
- Regular vertical profiles (every 2-4 weeks) of the concentration of CO_2 and other carbon cycle relevant tracers (carbon isotopes, CO, CH_4, O_2/N_2 ratio) at 7 locations across Russia. Measurements will be made in the lower troposphere using light aircraft to a height of 3000 m.
- Development and implementation of a continental scale meteorological and biogeochemical-modelling framework to allow a determination of net carbon balance of the study region.

Scientific/Technical Objectives and Innovation

Objectives

The principle objective of the project is the implementation of first components of a continental scale observing system to help determine the net carbon balance of Siberia and its variation from year to year. The complexity of this goal necessitates an integrated top-down and bottom-up approach. In brief, continuous surface flux measurements in key ecosystems at 4 locations and regular vertical profile measurements from aircraft in the lower troposphere at 7 locations will be merged with similar observations at the boundaries of the study domain. These surface and atmospheric observations will then be combined together to provide the basis of a continental scale meteorological and biogeochemical modelling framework.

TCOS-Siberia-E builds on the experience gained in a study evaluating the feasibility of determining the carbon balance of Eastern Europe and western Siberia by means of atmospheric and surface measurements combined with local process studies (EU project EUROSIBERIAN CARBONFLUX, EV5V-CT95-0116, Heimann, 2000). In that pilot study, a first set of monitoring sites was successfully established. These sites have now been operating for almost 3 years, providing the basis of a first estimate of the carbon balance of Western Siberia and European Russia.

TCOS-Siberia includes the following specific objectives:

- Development and implementation of a network of three long-term surface CO_2 flux-measuring stations in a west-east transect (Bialystok, Fedorovskoje, Zotino, Yakutsk) along 60N,

complemented by a station in the southern Siberian grasslands (Ubsu Nur near Kyzyl). As well as CO_2, at these stations fluxes of sensible and latent heat, as well as supporting meteorological variables will also be measured.

- Development and implementation of a network of vertical aircraft profile stations at 3 sites in a west east transect (Federovskoje, Syktyvkar, Zotino), complemented with 2 stations at the northern border of the boreal forest (Khatanga and Cherskii) and one station in the southern Siberian grasslands (Ubsu Nur). At these six stations vertical profiles of CO_2, its isotopes and other trace gases such as CO, CH_4 and the O_2/N_2 ratio will be measured with a regular (every 2-4 weeks) sampling schedule throughout the project.
- Integration of the project observational network with the networks of surface flux and atmospheric concentration measurements currently existing just beyond the periphery of the project target area (i.e. in Western Europe, Japan and China). Measurements will also be integrated with continuous trace gas measurements from a tall tower (250m) observational platform to be installed in central Siberia and operational within the next two years.
- Development of an integrated modelling system consisting of three coupled components
    - a mesoscale atmospheric model for the Eurosiberian target area,
    - a state-of-the-art biophysical and biochemical surface flux module for the description of the exchanges of CO_2, energy and water driven by the prevailing meteorology and remote sensing data,
    - a terrestrial biogeochemical model for the description of the longer-term cycling of carbon, carbon isotopes and nutrients.
- Inference of the spatio-temporal pattern in surface exchange fluxes by simulation runs of the modelling system in a data-assimilation mode.
- Assessment of the larger scale spatio-temporal variation of the overall carbon balance of the Eurosiberian region over a 6-year time period (1998-2004).
- Development of a future continental observing strategy, including optimization of sampling locations, precision and frequency of sampling, as well as possible improvements of measurement techniques. An assessment of the utility of novel approaches (e.g. satellite-based remote sensing of the CO_2 column integral) to assist with the determination of regional carbon balances will also be made.

The objectives of the extension include:

- Addition of a seventh aircraft sampling site at the eastern border of Poland (near Bialystok) providing a characterization of the air masses that enter the target region from the west.
- Addition of VOC analyses on all aircraft measurements in the boundary layer and the overlying free troposphere within year 2 and 3 of the project and determination of their contribution to the atmosphere-canopy carbon fluxes within the target study area
- Addition of soil carbon measurements (in situ and on laboratory samples) to determine a better characterization of soil decomposition rates as functions of climatic and edaphic parameters in order to improve the representation of heterotrophic respiration in the surface model.

Innovation

An accurate knowledge of the terrestrial component of the global carbon cycle has become a policy imperative and is expected to remain so for forthcoming decades. This is the case at the global scale and as well as for individual regions and countries. At the global level, the principle reason is the recognition that increasing atmospheric CO2 concentrations due to human activities are almost certainly leading to significant regional and global climate changes. It was this recognition that led to the United Nations Framework Convention on Climate Change and the Kyoto Protocol; the latter of which acknowledged the potential role of terrestrial systems as significant carbon sinks and sources. At a national level it is becoming increasingly recognised that an increasing fraction (up to 40%) of all terrestrial ecosystems

have been affected by direct human impacts (agriculture, pasture, forestry, fire management, etc.) with continuing concerns existing about the long-term sustainable use of these systems. In addition, many countries are increasingly interested in their terrestrial carbon balance because some UNFCCC-proposals which allow the sharing of carbon emissions among people or countries. Both national and international policy makers therefore require sound understanding of the mechanisms governing the carbon cycle if the agreed-upon measures are to achieve the desired result.

All these activities and interests depend on the provision of accurate and objective information about the state and degree of change in the various components of the terrestrial carbon cycle. Because of the many interacting factors affecting the terrestrial carbon balance both above and below the soil surface, such information must be obtained at high frequency and with a high spatial resolution. The cycling of carbon and nutrients in the terrestrial biosphere proceeds on time scales of decades and longer. This means that a long-term monitoring strategy is indispensable for the realisation of the above aims. A credible quantification of a continental wide carbon balance can be obtained using a "bottom-up" approach. For example by the compilation of local statistical inventories and point-wise flux measurements for various ecosystems, which are then aggregated to the regional scale. Alternatively, a "top-down" approach may be applied, in which atmospheric measurements of the concentration of the greenhouse gases are "inverted" to estimate magnitude and uncertainty of surface sources and sinks that are consistent with the observations. In order to relate such results with surface fluxes, it is necessary to implement a hierarchy of nested atmospheric meteorological transport models that can be applied in a forward and inverse mode.

Such a modelling framework must also incorporate terrestrial biogeochemical models to describe the cycling and exchanges of carbon between the surface and the atmosphere as a function of the local meteorology and the prevailing state of the ecosystem.

From atmospheric measurements of the CO2 concentration it has been inferred that a substantial net carbon uptake takes place in the northern hemisphere in temperate latitudes (Keeling et al., 1989, Tans et al. 1990), with a significant fraction over the continents. A more precise localization is currently heavily disputed (Fan et al., 1998, Rayner et al., 1999, Bousquet et al., 1999, Kaminski et al., 1999, Bousquet et al., 2000) and constitutes a high research priority (e.g. US carbon cycle plan, 1999).

Clearly, it is most likely that Siberia contributes in a substantial way to the northern hemisphere sink. But its magnitude is at present very poorly known. For example, inventory based estimates of the net carbon balance of Russian forests vary widely: ranging from a small source of 0.035 Pg C yr-1 (Houghton et al. 1987) to a significant sink of 0.485 PgC yr-1 (Kolchugina and Vinson 1993). Siberia constitutes one of the most important terrestrial components of the global carbon cycle: Area = 6 1012m2, Carbon stocks = 74 PgC in vegetation, 249 PgC in soils (Dixon et al., 1994), Net Primary Productivity = 1-3 PgC yr-1 (Schulze et al., 1999). Nearly 65% of the Siberian forest area lies in regions with permafrost. At present we have little empirical understanding of the role of this component in the global carbon cycle, how it reacts to past, present and future changes in climate and to increasing human impacts (fire, forest logging). Monitoring this large continental carbon store by a specific observing system constitutes a major challenge, but it is also a challenge of urgent scientific necessity.

The effective design of continental and global monitoring systems for CO2 and other climate relevant gases is currently the subject of discussions in a series of initiatives of the World Meteorological Organization (WMO) and the International Biosphere-Geosphere Program (IGBP) as part of the Global Climate Observing System (GCOS) and the Global Terrestrial Observing System (GTOS). We consider TCOS-Siberia as a prototype for such a continental monitoring study, and TCOS-Siberia should provide critical experience and information to assist in the design of these new international initiatives. We are aware that this project can only set the scientific stage for such a network, which will ultimately require governmental agreements at a later stage.

Obviously, long-term continental monitoring measurements by aircraft will not be possible at substantially more sites than envisaged in the present project. Therefore, in the long term, additional supplementary observational systems will have to be developed and implemented. Among these, two novel approaches appear very promising:

1. Remote sensing of the atmospheric CO2 concentration from space borne satellite platforms promises global and frequent coverage. But up to now one major hindrance has been the limited accuracy of the measurements. Because of this, in situ observations at the surface and within the lower troposphere will provide key information for the validation and possibly calibration of the satellite sensed signals. Ultimately, satellite data together with the surface and lower troposphere measurements will have to be assimilated together within a 4-dimensional modelling framework. A pilot study on the development of such a system is pursued in a recently initiated sister project by two of the project participants (COCO EU project funded under EESD-ENV-99-2, thematic priorities EESD-1999-2.1.1 and EESD-1999-2.2.2, 2002-2004).
2. Over continental regions, continuous monitoring of the CO2 concentration on tall (>200m) towers provides an alternative possibility to infer space-time variations of surface CO2 exchange fluxes on the regional scale (up to 1000km) (Bakwin et al., 1998). It is expected, that during the course of TCOSSiberia MPG.BGC will install a tall (~250m) tower in central Siberia near Zotino using institutional funding. This tower will be operated jointly with the Russian project participant IFOR-RAS. The surface and aircraft observations and the modelling activities in TCOS-Siberia will provide highly valuable additional information on how to relate the continuous measurements at the tower to the concentration in the mixed planetary boundary layer during daytime and the free troposphere above. The regional quantification of the carbon balance by surface flux measurements and by the top-down approach with inverse methods classically is based on concentration measurements of CO2. Although CO2 is the climatologically most relevant atmospheric trace gas, there exist several other carbon containing compounds such as CH4, CO and Volatile Organic Compounds (VOC's), which are also emitted by terrestrial ecosystems in a non-negligible amount. In the atmosphere most of these compounds are rapidly oxidized to CO2 with lifetimes ranging from hours to a few days (VOCs), to several months (CO) and up to a decade (CH4). These species bypass the flux measurements made with the eddy covariance technique (which determines only the local canopy-atmosphere CO2 flux), and they are usually not included in inverse atmospheric concentration calculations to infer regional surface carbon balances. Especially the emissions of VOCs (mostly isoprene and monoterpenes, emitted primarily by forests) have recently been shown to constitute a significant contribution to the net carbon balance of the vegetation in selected locations in the Amazon basin (Kesselmeier et al., 2002, see also review by Kesselmeier and Staudt, 1999).

A preliminary extrapolation to the globe based on existing measurements in Amazonia and Mediterranean forests yields VOC fluxes that are on the same order of magnitude as the net carbon balance of the global terrestrial biosphere (Kesselmeier et al., 2002 submitted). Virtually nothing is known of the emissions of VOCs from the vegetation in Siberia.

Within TCOS-Siberia CO and CH4 concentrations are routinely analyzed on all flasks collected in the aircraft-sampling program. As a novel measurement component, we propose in TCOS-Siberia-E additional measurements of VOCs on the regular aircraft-sampling missions and directly within and above the canopy during selected time periods in summer at the surface flux measuring sites of the TCOS-Siberia project.

This information will provide the observational basis to quantitatively infer the potential corrections that have to be applied to the carbon balance estimated by the classical CO2 only approaches. Since VOCs are also highly important for the tropospheric chemistry and precursors of aerosols (Andreae and

Crutzen, 1997), these measurements will also be of high value for regional and global chemistry and aerosol model calculations.

Partners

N°	Organisation	Country
1	Max-Planck Institute for Biogeochemistry, Jena	Germany
2	University of Heidelberg, Institut für Umweltphysik	Germany
3	Laboratoire des Sciences du Climat de l'Environnement, CNRS-CEA, Saclay	France
4	Free University of Amsterdam, Department of Geo-Environmental Science	Netherlands
5	Rijksuniversiteit Groningen, Centrum voor Isotopen Onderzoek	Netherlands
6	University of Tuscia, Department of Forest Science and Resource	Italy
7	Russian Academy of Sciences, Severtzov's Institute of Evolution and Ecology Problem	Russia
8	Siberian Branch Russian Academy of Sciences, V.N. Sukachev Institute of Forest	Russia
9	Siberian Branch Russian Academy of Sciences	Russia
10	Russian Academy of Sciences, Pacific Institute of Geography	Russia
11	University of South Bohemia in Ceske Budejovice, Department of Ecology	Czech Republic
12	University of Bialystok, The Institute of Chemistry	Poland

TOPOZ III - Towards the Prediction of Stratospheric Ozone III: The Partitioning of the NOy Components

EVK2-CT-2001-00102

http://www-imk.fzk.de/topoz-iii/

Instrument:	FP5 Research Project	Contract starting date: 01/01/2002
Total project cost:	2.718.129 €	Duration: 36 months
EC Contribution:	1.843.870 €	
Organization:	Forschungszentrum Karlsruhe GmbH - Technik und Umwelt, Karlsruhe, Germany	
Co-ordinator:	Wolfgang Kouker (wolfgang.kouker@imk.fzk.de)	
EC Contact person:	Claus Brüning (claus.bruening@ec.europa.eu)	

Objectives

Validation and application:

- Quality assessment of the derived datasets from MIPAS and SCIAMACHY.
- Validation of the improved CTMs.
- Application of the improved model technology in GCMs and a new estimate of the future evolution of the ozone layer.

Scientific achievements

- During the reporting period a comprehensive data set on atmospheric trace species relevant for NOy chemistry in the stratosphere on an additional episode was generated and validated against various other data. Significant progress was made with w.r.t. the dominating error source of the SCIAMACHY profiles, the ENVISAT pointing error. In addition, retrieval studies demonstrated that the BrO and NO2 profile retrieval is sensitive down to 12 km (cloud free conditions assumed).
- The simulation of Arctic winter 2002/2003 by the partners running CTMs reveal that the vortex build up and break up is reproduced in all models as a result of the well described short-term dynamics in the ECMWF analyses. Two weeks after the initialisation of the CTMs which based on MIPAS-ENVISAT data the simulated distribution of the long-lived species is in good agreement with the measurements. Only the results of the KASIMA model are already influenced by the too strong upward transport in the tropics. For chemically active species the model results differ with respect to absolute values as well as with respect to the distribution.
- Updated versions of the CCMs ULAQ and DLR-E39/C have been used for a best estimate to describe recent changes of atmospheric composition and climate and for a prediction of the recovery of the ozone layer. A detailed comparison of CCM results with respective other model data and available observations have been used for a critical estimation of uncertainties with regards to the future development of the ozone layer. The CCM results have been further analysed with regards to the interaction of dynamic, chemical, and radiative processes, particularly in polar regions of the upper troposphere and lower stratosphere. The investigations have focused on questions about the mutual influence of the greenhouse effect and ozone depletion, the impact of tropospheric and stratospheric aerosol chemistry, and the impact of natural forcing mechanisms on atmospheric long-term behaviour.

Socio-economic relevance and policy implications

- The application of datasets of the ENVISAT strengthens Europ's space industry.

- Scientifically based assessments on climate change are of ultimate interest of Europe's population.

Conclusions

The project brought together scientific working groups of different areas in atmospheric research. The people involved spent a considerable effort to work together on one scientific topic in a co-ordinated way. Beyond the technological and scientific success, this project plays its role in socially integrating different European nations by the personal experiences of each other and by bringing these experiences into the social environment of each partner outside the project.

Keywords

Climate change, ozone recovery.

Partners

N°	Organisation	Country
1	CSIC – Instituto de Astrofisica de Andalucia	Spain
2	University of Bremen	Germany
3	University of Karlsruhe	Germany
4	Karlsruhe Research Centre	Germany
5	Norwegian Institute for Air Research	Norway
6	University of Leeds	UK
7	Forschungszentrum Jülich	Germany
8	University of Utrecht	Netherlands
9	Université Pierre et Marie Curie, Service d'Aéronomie, Paris	France
10	University of Cambridge	UK
11	DLR – Oberpfaffenhofen	Germany
12	University of l'Aquila	Italy

TRACTOR - Tracer and Circulation in The Nordic Seas Region

EVK2-CT-2000-00080

http://www.ices.dk/ocean/project/tractor

Instrument:	FP5 Research Project	Contract starting date: 01.02.2001
Total project cost:	2.342.632 €	Duration: 36 months
EC Contribution:	1.887.530 €	
Organization:	University of Bergen and Bjerkens Center for Climate Research, Bergen, Norway	
Co-ordinator:	Truls Johannessen (truls.johannessen@gfi.uib.no)	
EC Contact person:	Georgios Amanatidis (georgios.amanatidis@ec.europa.eu)	

Objectives

Primary objectives:

- Describe and quantify the present strength and variability of the circulation and oceanic processes of the Nordic Seas regions using primarily observations of the long term spread of a tracer purposefully released into the Greenland Sea Gyre in 1996.
- Improve our understanding of ocean processes critical to the thermaholine circulation in the Nordic Seas regions so as to be able to predict how this region may respond to climate change.
- Assess the role of mixing and ageing of water masses on the carbon transport and the role of the thermohaline circulation in carbon storage using water transports and mixing coefficients derived from the tracer distribution.

Specific Objectives

1. Annual hydrographic, chemical and SF6 tracer surveys into the Nordic regions in order to:

- Measure lateral and diapycnal mixing rates in the Greenland Sea Gyre and in the surrounding regions.
- Document the depth and rates of convective mixing in the Greenland Sea using the SF6 and the water masses characteristics.
- Measure the transit time and transport of water from the Greenland Sea to surrounding seas and outflows. Document processes of water mass transformation and entrainment occurring to water emanating from the central Greenland Sea.
- Measure diapycnal mixing rates in the bottom and margins of the Greenland Sea basin using the SF6 signal observed there. Quantify the potential role of bottom boundary-layer mixing in the ventilation of the Greenland Sea Deep Water in absence of deep convection.

2. Monitor the variability of the entrainment of water from the Greenland Sea using time series auto-sampler moorings at strategic positions i.e., sill of the Denmark Strait, Labrador Sea, Jan Mayen fracture zone and Fram Strait. Relate the observed variability of the tracer signal in the outflows to convection events in the Greenland Sea and local wind stress events. Obtain a better description of deepwater overflow and entrainment processes in the Denmark Strait and Faeroe Bank Channel overflows and use these to improve modelling of deepwater overflows.

3. Monitor the tracer invasion into the North Atlantic using opportunistic SF6 measurements from other cruises: we anticipate that a number of oceanographic cruises will take place in the north-east Atlantic and the Labrador Sea. It should be possible to get samples from some cruises for SF6 measurements.

4. Use process models to describe the spread of the tracer to achieve better parameterisation for three-dimensional models. One reason that these are so resistant to prediction is that our best ocean models are as yet some distance from being good enough, to predict climate and climate change.

Scientific achievements and Conclusions

As by spring of 2004, the main results of TRACTOR are:

- The vertical mixing rates in the Greenland Sea gyre system have been quantified and found to be much higher than in other regions.
- The main pathways from the Greenland Sea into the ambient oceans have been identified.
- Information on the exchange and exchange rates between basins of the water marked by the tracer have been received from budgeting the tracer patch.
- Two modes of ventilation are identified in the Greenland Sea. The first is the formation of eddies with subsequent ventilation at mid depth during the collapse of the eddies and the second is overturning. The eddy mode seems to play an important role during the tracer experiment with a volume transport estimated to 0.01 to 0.02 Sv while the limited overturning present during the main part of the experiment seemed to contribute to 0.1-0.2 Sv.
- Different pathways from the Greenland Sea dominate during different modes of the North Atlantic Oscillation, the natural variability in atmospheric forcing. In the NAO + mode a bifurcation of the pathways occur with one route from the Greenland Sea through the Jan Mayen channel, along the Jan Mayen Ridge and then into the Faeroe-Shetland channel and the other route along the shelf rise to the Greenland Shelf on route to the Denmark Strait. In the NAO- mode waters from the Greenland Sea will mostly select the western path.
- The first appearance of the tracer at the Greenland-Scotland Ridge was in the Faeroe Bank channel 2.5 years (± 2 months). This is consistent with the different pathways for the water from the Greenland Sea connected to the NAO modes as mentioned above, since NAO + forcing greatly dominated during the experiment.
- The circulation and mixing characteristics of the 20 km resolution Nansen Centre version of the Miami Isopycnic Coordinate Ocean General Circulation Model (MICOM), lead to greatly improved and a representative time-space distribution of the released SF6. It is concluded that simulated distributions of tracers provide detailed insight into isopycnal and diapycnal diffusion parameterizations, and that a data-model comparison can be used to constrain the strength of the mixing schemes.
- The 40 km, and in particular the 20 km, resolution version of the model system are able to describe the main features of the observed CFC-11, CFC-12, ^{137}Cs and SF_6 concentrations in a realistic way. In fact, the performed simulations show that OGCMs used in climate research should be evaluated based on some of the key tracers, including SF6, to assess, and by that to improve, the model's ability to reproduce the main features of the key ventilation processes of the ocean climate system.
- The results from the tracer release experiment will be used for a modelling inter-comparison exercise. Preliminary results from a GCM indicate that it seem to accelerate the general circulation relative to what is observed from the tracer field. A clear need for more detailed inter-comparison between the tracer field and the most frequently used GCMs are needed to improve these models which results are frequently used in guidance of policy making (see IPCC-report).
- New information of the transformation of dissolved inorganic carbon along the East Greenland Current, and of the anthropogenic carbon inventory within the Nordic Seas, and a new hypothesis on how ice formation enhances air-sea flux of CO2.
- During the TRACTOR period an auto-sampler collecting deepwater has been developed. One successful deployment and retrieval of the auto-sampler were done in the Denmark Strait. The

water is now being measured for CFC's. The titanium bags used need to be of a larger volume to be able to sample for SF6 and a new design of water collecting bags are under development.

Socio-economic relevance and policy implications

European dimension of the problem

TRACTOR has investigated the circulation of the Nordic Seas. The area has been considered crucial to the general circulation of the oceans, and this interlinked with climate change processes. A better understanding of the processes involved in climate change that affects Europe specifically and the globe in general and a better predictability of climate change are important for many aspects of the economy, politics, welfare and cultural and social affairs. Better detection and prediction of anthropogenically forced climate changes, as well as understanding the natural backdrop of changes, will form a better basis for policy making.

Contribution to developing S&T co-operation at international level

The consortium of TRACTOR has brought together skills and analytical methods which are unique in the world. It was built on existing capacities brought together in a scientific task that has not been attempted before. With the contributions from the different partners, a critical mass of personal resources and infrastructure (such as research vessels and computers) was achieved. The project has fostered closer ties between the observational and climate modelling communities in Europe, and laid the ground for further development of European modelling institutions to improve the model skills to describe global ocean circulation and its impact on climate.

Contribution to policy design or implementation

An improved capability to model oceans and oceanic processes will reduce uncertainties in the projected forecasts of the climatic response to greenhouse gas forcing.

- It will form a better basis for choosing the most relevant policies to deal with the problems of climate change and the implementation of the Kyoto protocol.
- The model improvements will specifically address uncertainties related to processes of high relevance for the regional climate, the project has contributed to more reliable regional climate forecasts.
- The improved ocean modelling capabilities is of relevance for the use and management of oceans and ocean resources, in particular living resources.
- The improved ocean modelling capabilities will also be of high relevance for the potential forecasting of water management in Europe.

Quality of life

There is considerable variability in the climate of Europe. Most areas of human activity are affected by climate change in the region. It is necessary to improve our understanding of this variability and the range of the variability in future scenarios.

If ocean circulation should change or the decadal variability should tend to shift into a state where one of the NAO modes is dominant, this would impact strongly on life in our part of the globe, in a way which is economically quantifiable. Although parts of this variability may be chaotic and non-predictive, the project has contributed to a better understanding of the patterns, which may lead to some type of predictability. A better understanding of oceanic processes lies at the heart of this problem.

Monitoring and creating jobs in the Community (including use and development of skills)

The project has trained of PhD students in physical and chemical oceanography and modelling oceanic processes. It has lead to improved knowledge and skills within the areas of expertise of each partner and the scientific community. Some technical advances have been made on deep water automatic sampling.

Partners

N°	Organisation	Country
1	University of Bergen	Norway
2	University of East Anglia, Norwich	UK
3	Göteborg University	Sweden
4	Nansen Centre, Bergen	Norway
5	Norwegian Polar Institute, Tromsoe	Norway
6	Marine Research Institute, Reykjavik	Iceland
7	International Council for Exploration of the Seas, Copenhagen	Denmark

2. Environment and Health

ANEMONE - Assessment of neurobehavioural endpoints and markers of neurotoxicant exposures

QLK4-CT-2001-00186

http://www.anemone-project.dk/

Final report: http://ec.europa.eu/research/quality-of-life/ka4/pdf/report_anemone_en.pdf

Instrument:	FP5 Research Project	Contract starting date: 01/01/2002
Total project cost:	1.098.000 €	Duration: 36 months
EC Contribution:	1.040.000 €	
Organization:	University of Southern Denmark, Institute of Public Health, Odense, Denmark	
Co-ordinator:	Philippe Grandjean (pgrandjean@health.sdu.dk)	
EC Contact person:	Tuomo Karjalainen (tuomo.karjalainen@ec.europa.eu)	

Objectives

This project aimed at a) improving methods for assessment of hazardous exposures and for early detection of adverse effects on cognitive functions, and b) applying these methods in determining developmental risks due to contaminated seafood. For this purpose, sophisticated analytical chemical methods were modified and applied for identification and quantification of organohalogen compounds in human blood to ascertain levels of exposure from the foetal stage to the age of 7 years. At the same time, highly sensitive biomarkers based on blood assays were further developed, and their validity were determined using exposures to seafood contaminants in intact animals, in cell cultures, and in human blood cells. These biomarkers were then applied in the 7-year-old children, who were also examined with detailed neuropsychological tests to assess early cognitive damage.

Results and Milestones

Modern analytical chemical methods have been further developed to characterize in detail the exposure to a wide variety of organohalogen compounds, including polychlorinated biphenyls (PCBs). In human serum from pregnant women in the Faroe Islands, the relative OH-PCB and PCB congener distributions were similar to those observed elsewhere, but 7-year-old children had significantly increased OH-PCB concentrations relative to the PCBs. While 4-OH-CB187 was the most abundant OH-PCB metabolite in the mothers, 4-OH-CB107 was the most common congener in children. As a traditional food source, fulmars and fulmar eggs were examined for OH-PCB and PCB concentrations. This is the first time OH-PCBs are analysed in a human food source. Because the metabolites are present in the non-hatched fulmar egg, and no metabolizing activity is present in the newly laid egg, the OH-PCBs must have been transferred prior to egg laying. Three OH-PCBs predominated, i.e. 3-OH-CB153, 4-OH-CB146 and 4-OH-CB187, a pattern that differs only slightly from the one that we have documented in blood from Faroese women The PCB levels in the adult fulmars are in the same concentration range (5-30 μg/g l.w.) as has been seen in the pilot whale, with CB-153 as the most abundant PCB congener. Polybrominated diphenyl ethers (PBDEs) showed similar serum concentrations in the children when compared to serum from their mothers 7 years before, but the PBDE congener pattern was again different. Thus, the major congener in the mothers was BDE-47, while BDE-153 in the serum from the children. The children also had the highest median BDE-209 level. The maternal serum PBDE concentration was about twice the milk concentration of the ΣBDE, thus suggesting that these substances are not ass efficiently excreted in milk. The PBDE concentrations increased substantially over time, as indicated by analysis of milk collected from the same population in 1987, 1994, and 1999. The most recent milk concentrations were

among the highest in Europe. Also, the most recent samples were dominated by BDE-153, which is highly surprising. These findings document the usefulness of the advanced chemical analysis methods applied in regard to determining specific components and their metabolites, to which humans are exposed, in documenting food chain biomagnification patterns, and in discerning temporal trends. Two promising neurotoxicity biomarkers, monoamine oxidase type B (MAO-B) and muscarinic acetylcholine esterase receptors (mAChRs), were first validated in a series of experimental studies that included advanced in vitro testing. These biomarker assays were established with appropriate quality assurance, and reference data were obtained from adult subjects thought to be exposed only to low levels of pollutants, and comparison data have been obtained from subjects with excess exposure to alcohol. The two biochemical parameters are expressed both in the central nervous system and in peripheral blood. Experimental studies have now documented the associations between effects within the nervous system and in the blood. Based on a survey of the literature available and preliminary data from the cohort, the following compounds were tested: CB-28, CB-77, CB-105, CB-115, CB-153, BDE-47, and 4-OH-CB-107. Only limited effects were documented in blood cells tested in vitro. In vivo rodent studies explored the effects of methylmercury and CB-153 alone and in combination with regard to the neurotoxicity biomarkers in brain tissue and in peripheral blood. The exposure to methylmercury (MeHg) at 1 mg/kg/day affected the mAChRs both in brain areas and lymphocytes of the mature and immature animals. Thus, based on these results, the lymphocyte mAChRs can be considered as biomarkers of CNS effects. Moreover, MeHg enhanced cerebral and lymphocyte MRs more in dams than in pups in accordance with the higher Hg levels detected in the adult tissues. The concomitant prenatal exposure to PCB153 (20 mg/kg/day) interfered with the biomarker level both in brain and lymphocytes. In particular, the trend of mAChR changes caused by MeHg and PCB153 in the lymphocytes partially mirrored that of the cerebellum. In animals exposed to the lower MeHg dose (5 mg/kg/day MeHg) no effects were seen on this endpoint. MeHg at 1 mg/kg/day and PCB 153 at 20 mg/kg/day either alone or in combination also induced a decrease on MAO-B activity in the cerebellum of the male offspring only.

Blood samples were collected from clinical examinations of 7-year-old children belonging to a birth cohort established at the Faroe Islands. Although the sampling and pre-treatment of blood cells were successful, the biomarker analyses failed to show any clear association with biomarkers of prenatal or current exposures to MeHg and PCB. The neuropsychological tests carried out showed associations with prenatal MeHg exposure levels similar in magnitude to those previously found to be statistically significant in a larger cohort. However, due to the smaller sample size in the present study, the statistical power was less. The neuropsychological outcomes were not associated with the two neurotoxicity biomarkers. The lack of associations of the biochemical neurotoxicity biomarkers suggests that these parameters are not yet applicable for epidemiological use, but may be useful in follow-up studies with repeated assessments of individual subjects. Structural equation models were found to add substantial insight to the statistical data analysis, because they combine information across outcomes in a joint analysis. An additional finding was that neuropsychological tests appeared less sensitive to neurotoxic exposures when carried out in children younger than 7 years. These statistical methods should be applied in future studies with multiple exposure parameters and multiple outcomes to explore dose-response relationships. The study findings suggest that further work is indicated on characterising chemical exposures associated with seafood intake. The lack of statistical significance in the present study should not be interpreted as an absence of correlations and the absence of any neurotoxic risk. In extended studies, standardised clinical tests, rather than effect biomarkers should be emphasised. Such epidemiological studies should emphasise statistical power, and populations should be greater than the cohort studied in ANEMONE, and preferably with at least as large an exposure range and limited impact of confounders.

Benefits and Beneficiaries

This project has resulted in:

1. New documentation on halogenated organic compounds as contaminants of marine food;
2. Discovery of increased concentrations of hydroxyl-PCB metabolites in serum samples from children;
3. Documentation of increasing contamination of human milk with polybrominated diphenyl ether, with a changing pattern of congeners;
4. Extended documentation of neurotoxicity biomarker validity in experimental studies;
5. Documentation of neurotoxicity biomarker variability in children and the lack of clear association with exposure biomarkers and with neurobehavioural deficits;
6. Extended documentation of neurotoxic risks to children caused by complex exposures from maternal ingestion of contaminated marine food and of the susceptibility of the foetus and young child to adverse effects on cognitive function; and
7. Demonstration that advanced statistical methods, especially structural equation models, are highly useful for analysing complex data that include several exposure parameters, several outcome variables, confounders, and unknown degrees of parameter imprecision. These models may even be extended to applications in prospective studies and in calculations of benchmark dose levels.

These results will be of particular relevance to the research community and to authorities responsible for food safety and for setting permissible exposure limits to environmental pollutants.

Future Actions

The project web site will be kept afloat and will be updated with future publications resulting from this project.

Partners

N°	Organisation	Country
1	University of Southern Denmark, Institute of Public Health, Department of Environmental Medicine, Odense	Denmark
2	The Faroese Hospital System, Department of Occupational and Public Health	The Faroe Islands
3	Fondazione Salvatore Maugeri, Clinica del Lavoro e della Riabilitazione	Italy
4	Stockholms Universitet, Department of Environmental and Chemistry, Stockholm	Sweden
5	Landesamt für Gesundheit und Arbeitssicherheit des Landes Schleswig-Holstein, Kiel	Germany

BEEP - Biological effects of environmental pollution in marine coastal ecosystems

EVK3-CT-2000-00025

http://beep.lptc.u-bordeaux.fr

Final report: http://ec.europa.eu/research/endocrine/pdf/beep_en.pdf

Instrument:	FP5 Research Project	Contract starting date: 01/02/2001
Total project cost:	5.629.462 €	Duration: 36 months
EC Contribution:	4.000.000 €	
Organization:	Université Bordeaux I, LPTC	Bordeaux, France
Co-ordinator:	Philippe Garrigues (p.garrigues@lptc.u-bordeaux.fr)	
EC Contact person:	Tuomo Karjalainen (tuomo.karjalainen@ec.europa.eu)	

Executive Summary

Biological markers allow the direct determination of pollutant impact on living organisms in aquatic systems. While new emerging biomarkers are actually under evaluation, some common markers are in a validation-phase and may be used as assessment tools for the quality of the marine environment. The goal of the European Research Project BEEP (Biological Effects of Environmental Pollution in Marine Ecosystems) was to evaluate the use of biological markers determined in marine organisms as a means of assessment of chemical contamination. This integrated multi-disciplinary, -site and -marker research project combines special European expertise in biology, biochemistry, ecotoxicology, environmental chemistry and data handling has enabled a comprehensive study of selected coastal European environments and their responses when exposed to varying levels of pollution and numerous chemical contaminants (heavy metals, pesticides, hydrocarbons, chlorinated compounds). Different types of coastal European environments (Baltic Sea, North Atlantic Sea, and Mediterranean Sea) have been investigated by 30 participants who have co-operated on the three selected coastal environments through a long term study. Further more two joint studies organised in the laboratory of Aquamiljo (RF Rogaland, Stavanger) have put together during several days several dozens of BEEP researchers who have performed complementary works on an experimentally polluted mesocosms.

The BEEP Project was also part of the EU funded projects supported by the European Commission (RTD programme) within the EESD (Energy, Environment and Sustainable Development) programme of the EC. It belonged to the IMPACTS cluster coordinated by the European Commission's DG Research.

The specific objectives of the project were as follows:

- To develop new biological markers ranging over different levels of biological organizations.
- To validate the use of selected biomarkers in specific sites for both routine assessment of chemical contamination and for the improvement of national and international monitoring programmes
- To prepare information and advices for user group, policy-makers and fishery institutions about biological effects of chemical contamination on coastal marine resources,
- To determine the effects of environmental contamination on end-users (fisheries, marine aquaculture)
- To establish a network of biomarker researchers through European countries.

In order to assess these objectives, the research programme has been organised into different workpackages:

- *Project Management (WP0)*: The main coordinator and the 5 workpackage coordinators were part of the coordination committee responsible for the integration of the works of the partners, the communication between participants, the exploitation of the results and the production of deliverables. The BEEP Web site has been set up as an essential tool for the project partner (infos, database, presentations, results).
- *Novel biomarkers (WP1)*: Development of new biomarkers of stress/exposure at both the cellular levels and subsequent effects at the population level. This workpackage was in charge of developing new approaches in biomarker methodology to be transferred to in situ studies.
- *Biomonitoring Programmes in Baltic Sea (WP2), Mediterranean Sea (WP3)* and *North Atlantic Sea (WP4)*: Selected sites in each coastal environment have been monitored during three years for deploying a set of 5 common biomarkers for all the workpackages. In addition other specific biomarkers have been also studied for in situ validation.
- *Data Management (WP5)*: Various data treatment approaches have been developed to sort and to analyse the data: expert system, statistical analyses and pollution ranking scale based on biomarkers. A data base has been built for an easy access to all the BEEP partners.

The expected achievements of the BEEP project have been obtained:

- Improvement and development of the knowledge on biological markers in marine organisms exposed to chemical stresses in coastal environments
- Selection a standardized battery of biological markers for implementation of biomarker techniques in national/international monitoring programmes (OSPARCOM, HELCOM)
- Improvement the quality of data related to biomarker measurements in view of coming EU directives for the environment and the consumer protection.

This final report present the results obtained during the three-year project by all the BEEP participants and has been organised according to the different workpackages. Three workshops (Starting meeting, Plymouth, 2001; Athens Workshop, 2002; Barcelona Workshop, 2003) have brought together more than 60 researchers and students representing the 30 organisms participating to the BEEP Project. More than 110 publications, 130 presentations in international meetings and 35 PhD dissertations have been produced in the framework of the BEEP project. A comprehensive book compiling all the results will be prepared in the two next years. Finally the BEEP project has been able to create an active European network of researchers involved into the biomarker approaches into the marine coastal ecosystems, of which results are supporting the implementation of several EU directives dealing with the aquatic environment.

Partners

N°	Organisation	Country
1	Université Bordeaux I, LPTC	France
2	Università 'Amedeo Avogadro', Dip. Di Scienze e Avanzate Tecnologie, Alessandria	Italy
3	Finnish Institute of Marine Research, Helsinki	Finland
4	IFREMER DEL/PC, Nantes	France
5	RF-Rogaland Research, Stavanger	Norway
6	NERC – Plymouth Marine Laboratory	UK
7	Universidad del Pais Vasco, Biologia Zlularra cta Histologi Laborategia, Bilbao	Spain
8	National Center for Marine Research, Institute of Oceanography, Anavissos	Greece
9	Aristotle University of Thessaloniki, School of Biology, Dept. of Biology	Greece
10	Université du Havre, Laboratoire d'Ecotoxicologie	France

11	CSIC – Departament de Quemica Ambiental, Girona	Spain
12	Université de Bretagne Occidentale, Institut Universitaire Européen de la Mer, Plouzane	France
13	CTIS, Rillieux la Pape	France
14	Technische Universiät Berlin, Institut für Ökologie	Germany
15	Göteborg University, Department of Zoophysiology	Sweden
16	Alfred Wegener Institutes for Polar and Marine Research, Hamburg	Germany
17	Institute of Ecology, Vilnius	Lithuania
18	Stockholm University, Institute of Applied Environmental Research, Laboratory for Aquatic Ecotoxicology	Sweden
19	Norwegian University of Science and Technology, Dept. of Zoology, Trondheim	Norway
20	University of Reading, Division of Cell and Molecular Biology	UK
21	Centre de Recherche INRA, Lab de Pharmaco-Toxicologie Cellulaire et Moléculaire, Antibes	France
22	Institut für Ostseeforschung Warnemünde, Rostock	Germany
23	Finnish Game and Fisheries Research Institute, Helsinki	Finland
24	Bundesforschungsanstalt für Fischerei, Institut für Fischerökologie, Cuxhaven	Germany
25	Marine Chemistry and Biochemistry Department, Institute of Oceanology, Sopo	Poland
26	Gdansk University, Biological Station, Gdansk-Sobieszewo	Poland
27	Tel Aviv University, Faculty for Life Sciences, Inst Nature Conservation Research	Israël
28	Institute of Applied Ecology, Broderstorf	Germany
29	National Cancer Institute, Toxicological Evaluation Unit, Genova	Italy
30	University of Plymouth, Plymouth Environmental Research Center	UK

BIOCET - Bioaccumulation of persistent organic pollutants in small cetaceans in European waters: transport pathways and impact on reproduction

EVK3-CT-2000-00027

http://www.abdn.ac.uk/biocet

Final report: http://ec.europa.eu/research/endocrine/pdf/evk3-2000-00027-final-pr-rep_en.pdf

Instrument:	FP5 Research Project	Contract starting date: 01/01/2001
Total project cost:	1.616.510 €	Duration: 37 months
EC Contribution:	1.200.000 €	
Organization:	University of Aberdeen, Zoological Institute	Aberdeen, United Kingdom
Co-ordinator:	Graham J. Pierce (g.j.pierce@abdn.ac.uk)	
EC Contact person:	Tuomo Karjalainen (tuomo.karjalainen@ec.europa.eu)	

Objectives

This project aimed to quantify and model the process and time-course of bioaccumulation of persistent organic pollutants (POPs) in small cetaceans (focusing primarily on female common dolphins *Delphinus delphis* and harbour porpoises *Phocoena phocoena*) in NE Atlantic waters. This involved collecting individual-level and population-level datasets for use in comparisons and models. Seven partner institutions in five European countries worked over three years on nine workpackages. Data were collected on histopathology, reproduction, age, diet, inorganic pollutants and POPs. The objectives of the project were then to:

- Identify and model pathways of POP bioaccumulation· Identify trophic links contributing to bioaccumulation
- Compare reproductive success between populations· Identify areas in which the cetaceans studied are vulnerable to effects of bioaccumulation
- Compare reproductive success between individual females, in relation to age and diet
- Quantify and model the time-course of bioaccumulation in female porpoises and dolphins
- Provide synthesis and recommendations on issues related to the conservation of small cetaceans and the management of pollution in coastal zone and oceanic waters
- Disseminate and publish results on these studies

Scientific achievements

Co-ordination (WP1): Calibration workshops were held to ensure harmonised data collection and analysis. The project website has been updated (http://www.abdn.ac.uk/biocet) and project work has already appeared in several publications and conference presentations. Sample material has been preserved in sample banks. All project data have been put together in a series of linked databases that will ultimately become more widely available.

Sampling (WP2): Sample collection extended over almost 2.5 years, accessing stranded and by-caught cetaceans through local stranding schemes, as well as sampling prey species.

Pathology (WP3): There was considerable geographic variation in causes of mortality, e.g. the relative importance of pathological causes and fishery by-catch. There was evidence of Brucella infection in the

Dutch and Scottish harbour porpoise populations. Only for Belgium has little evidence of *Brucella* been found despite testing for it.

Age (WP4): Age readings were completed and used to derive growth curves for three species. A CD-ROM of images to assist future practical work was prepared. There were regional differences in sample age structure for common dolphins and harbour porpoises, with a preponderance of old animals in the Dutch porpoise population.

Reproduction (WP5): Reproductive status was determined for all studied animals, and counts and measurements on ovarian scars were taken for target individuals. Age at sexual maturity and pregnancy rates were derived for each population. Several lines of evidence indicate that corpora scars do not usually provide a reliable indicator of past pregnancies in small cetaceans. The pregnancy rate in Dutch harbour porpoises was especially low.

Diet (WP6). Stomach contents were analysed when available and analysis of blubber fatty acid profiles was completed for all target animals and selected prey species. Fatty acid profiles showed seasonal, regional, ontogenetic and interspecific variation, some trends being readily interpretable in terms of likely dietary variation. Quantitative fatty acid analysis allowed average diets to be predicted. However, cetacean fatty acid profiles are distinct from those of most putative prey and further calibration is needed.

Persistent organic pollutants (WP7): POP analyses were completed (in collaboration with CEFAS and the UK Strandings Project for UK samples) on all target animals and selected prey species, including determinations of the relatively new brominated flame retardant (BFR) hexabromocyclo-dodecane (HBCD) (not mentioned in the contract). HBCD is a high production volume (9500 tons within the EU in 2001) BFR used in the building industry. Highest HBCD levels occurred in harbour porpoises stranded on the coasts of the Irish Sea and the NW coast of Scotland, but the residues contained exclusively the relatively uncommon a-isomer. Levels of tributyltin in liver of harbour porpoises from the North Sea ranged at the highest end of levels reported. Median levels of S18-PCBs and CB153 in harbour porpoises from the southern North Sea, and common dolphins from the Western Channel and the Bay of Biscay were above the threshold levels for effects on reproduction as reported in the literature for the bottlenose dolphin and the harbour seal.

Toxic elements (WP8): As for WP7, some analyses were carried out in collaboration with CEFAS (UK) and both cetacean tissues (kidney, liver) and prey were analysed. Levels of mercury in liver and cadmium in kidney correlated well with age in a group of common dolphins that mass-stranded on the coast of Brittany (France). A strong relationship between age and mercury was seen in most studied small cetacean populations, although regional differences were also seen.

Synthesis (WP9). POP levels in female common dolphins were shown to be linked to diet, area and reproductive status, although not related to age; results for harbour porpoises indicated only area effects. Cadmium concentrations appeared to be closely linked to diet. The number of scars recorded on common dolphin ovaries was correlated with mercury burdens, and to a lesser extent to POP burdens and diet. Transfers of organic and metallic pollutants via food were estimated.

Socio-economic relevance and policy implications

The project is relevant to the conservation of small cetaceans and the management of pollution in coastal zone and oceanic waters. Porpoises and dolphins eat fish and invertebrates (e.g. squid and octopus) that are also eaten by man. Effects on reproduction in cetaceans provide a possible model for effects that might be seen in human communities with a substantial per-capita consumption of seafood. The study has highlighted areas where cetaceans carry high burdens of pollutants, levels sometimes exceeding

those known to affect reproduction. Pregnancy rate in Dutch harbour porpoises was particularly low and, taken together with high PCB levels, skewed age structure and presence of *Brucella*, suggests that this population is particularly at risk. The PBDEs found were exclusively tetra- to hexa-BDEs that are prominent in the commercial penta-formulation. This proves that the EU has been right in focusing its main restrictive policy on this mixture.

Keywords

Cetaceans, persistent organic pollutants, bioaccumulation, reproduction

Partners

N°	Organisation	Country
1	University of Aberdeen, Department of Zoology, School of Biological Sciences	UK
2	National Natuurhistorisch Museum of Leiden	Netherlands
3	Netherlands Institute for Sea Research, t' Horntje	Netherlands
4	Université de la Rochelle	France
5	CSIC - Instituto de Investigaciones Marinas, Bouzas, Galicia	Spain
6	University College, Cork	Ireland
7	Centre de Recherche sur les Mammifères Marins, Université de la Rochelle	France

COMPARE - Comparison of exposure-effect pathways to improve the assessment of human health risks of complex environmental mixtures of organohalogen

QLK4-CT-2000-00261

http://www.compare-project.info/

Final report: http://ec.europa.eu/research/quality-of-life/ka4/pdf/report-compare_en.pdf

Instrument:	FP5 Research Project	Contract starting date: 01/01/2001
Total project cost:	1.874.905 €	Duration: 45 months
EC Contribution:	1.900.000 €	
Organization:	Vrije Universiteit, Inst for Environmental Studies, Amsterdam, Netherlands	
Co-ordinator:	Abraham Brower (bram.brower@ivm.vu.nl)	
EC Contact person:	Tuomo.Karjalainen (tuomo.karjalainen@ec.europa.eu)	

Objectives

The major objective of this project was to:"provide a mechanism-based approach for the assessment of human health risks from exposure to complex environmental mixtures of halogenated phenolic compounds (HPCs). The Compare project involved studies on synthesis, identification and analysis of HPCs; on maternal-to-fetal transfer kinetics (role of TTR binding protein) in rodents and birds, on in vitro endocrine potency of HPCs; on developmental reproductive and neurobehavioural toxicity in rats, and on clinical epidemiological studies involving a Child Development cohort and a Fishermen and Fishermen's Wives Adults cohort. Finally, all the results from the Compare project were used to perform an integrated and comparative risk assessment for exposure to complex mixtures of environmental chemicals". For this purpose consolidated information on human individual exposure to HPCs, and on adverse health outcome of HPC exposure in laboratory animals, and in human individuals is included as this forms the basis for the integrated and comparative risk assessment.

Results and Milestones

Human exposure assessment to HPCs

An assessment of exposure of human individuals to halogenated phenolic compounds (HPCs) has been performed within the Compare project. This required the development of proper analytical chemical methods for determination of a variety of HPCs representative for several classes of contaminants and/or their metabolites, such as polychlorinated biphenyls (PCBs) and their hydroxylated metabolites (OH-PCBs); p,p'-DDE, pentachlorophenol (PCP), several representatives of brominated flame retardants, like 2,4,6-tribromophenol (TBP), brominated diphenylethers, BDE 47, and its hydroxy metabolite (6-OH-BDE 47), and hexabromocyclododecane (HBCDD). These methods were successfully developed by the Group of Prof. Bergman from Stockholm University, including an interlaboratory calibration study, involving three laboratories from participants, showing a coefficient of variation between the laboratories below 10%. Furthermore, these compounds and some of their phenolic metabolites were successfully synthesized by the Stockholm group for the purpose of e.g., reference standards. Finally a stability study was performed and it was concluded that prolonged storage of serum and plasma at –20ₒC warranted proper analysis of HPCs with a slight preference towards serum as a matrix.

Analyses of HPCs in human serum have been performed in several study cohorts within and outside of the Compare project. These included: a) the Groningen Child Development Cohort, involving analysis of HPCs in maternal and in foetal cord blood samples from 90 pregnant mothers and their children; b) Swedish Fishermen and their Wives Cohort involving about 400 volunteers; c) two relatively high exposure cohorts, one from Slovakia (close to former PCB factory) and one from Faroe Islands (high dietary intake due to e.g., whale blubber consumption).

Conclusions from the human HPC exposure studies are: Human individuals are exposed to HPCs. The levels of HPCs found in background exposure populations analysed range from low PPBs to the PPM level for phenolic metabolites of PCBs and for pentachlorophenol. In contaminated areas the concentrations of HPCs found are around 4 to 10 times higher than in the background population of pregnant mothers in the Netherlands.

The brominated HPCs are present at low PPB levels in human serum and in cord serum. The concentrations normalized for lipid content are in general 1- 4 times higher in the foetus as compared to the mother, indicating that the placenta is no barrier for these compounds. Apparently, the HPC binding protein, TTR in the serum is not a major factor for the transfer of HPCs from mother to foetus and from blood to brain

Hazard assessment of HPCs in experimental animals

The hazard assessment of HPCs was based on a) two-generation experimental animal studies, using Wistar rats as model species, focussing on developmental reproductive and neurobehavioural effects, following exposure of dams to HPCs from day 10-16 of gestation; b) kinetic studies in rats and birds and c) in vitro studies on endocrine effects of HPCs. The developmental reproductive studies in rats were performed by the group of Brouwer, at the Institute for Environmental Studies, Vrije Universiteit, Amsterdam, the neurobehavioural studies in rats were performed by the group of Regan.

Dublin University, and at the Amsterdam group, with the help of Lillienthal from University Duesseldorf, Germany.. In Uppsala University, the group of Brandt has performed comparative kinetic and effects studies with HPCs in birds, rats and knockout mice. Finally, the Amsterdam group also performed the in vitro endocrine activity experiments of HPCs.

The preliminary conclusions on developmental toxicity of HPCs are the following: Overall the in vitro as well as the in vivo data generated during the Compare study indicate that PCBs, their hydroxyl metabolites (OH-PCBs), and the brominated HPCs can induce long lasting developmental reproductive and neurobehavioural changes in offspring at low dose levels of exposure during pregnancy, i.e., at doses well below the levels that would induce sub-clinical or overt toxicity in dams, or offspring. The HPCs also show endocrine activity in in vitro studies, in particular on the thyroid and the estrogenic pathways. Furthermore, there are changes in thyroid hormone and oestrogen levels observed in offspring following exposure of dams to several HPCs. Some of the in vivo changes are already observed at the lowest doses used in this study, therefore it is not possible to give an accurate indication of No Observed Effect Levels (NOELs), but we have Lowest Observed Effect Levels at 0,1 mg/kg per day (at exposure during pregnancy for 7 consecutive days).

There are some similarities and also some differences observable between the various classes of HPCs. Overall the PCBs and their hydroxy metabolites are more active on the thyroid system and on developmental neurobehavioural changes on prepulse inhibition and on open field locomotion and neuroplasticity. Effects on the estrous system (hormones and cycle) and on spatial learning are observed in a more comparative way between the chlorinated and brominated HPCs studied.

In birds, the HPCs studied were injected Japanese quail eggs to investigate possible long-term adverse (reproductive and behavioural) effects. Hatchability by a phenolic PCB metabolite (4-OHCB-107) was reduced in the two highest doses, but no effects on reproductive behaviour, or gonadal weight were observed. Egg laying was not affected. This indicates that the metabolite 4-OH-CB 107 has a low developmental impact on birds, like Japanese quail. 4-OH-CB 187 also showed a high lethality early during embryonic development in the Japanese quail. At a dose not causing embryomortality there were no effects on reproductive behaviour, egg production or plasma concentrations of thyroid hormones in the adult birds. 6-OH-BDE 47 was highly toxic to early embryos

Human clinical-epidemiological studies on HPCs and health outcome

In the Compare project human clinical-epidemiological studies on possible associations between health outcome and exposure to HPCs were performed as well. Two study cohorts were included in the Compare project, namely: a human adult cohort: the Swedish Fishermen and fishermen's wives studied by the group of Prof. Hagmar, Lund University and a human infant cohort: the Groningen Child Development Cohort, studied by the group of Prof. Sauer, Groningen University. The Swedish Fishermen and fishermen's wives cohort study was aimed at exposure to the HPCs: CB 153, p,p'DDE, the hydroxyPCBs and BDE 47. East and West coast fishermen and their wives were compared, due to their different dietary and environmental exposure level to HPCs. The health outcome was primarily focused on fracture incidence, bone mineral density and endometriosis i.e., markers sensitive to e.g. estrogenic effects. The Groningen Child Development Cohort was aimed at exposure of mother's and their children (cord blood) to the following HPCs: 4-OH-CB-107, 4-OH-CB-187 and 4-OH-CB-146, PCB 153, TBBPA, 2,4,6-TBP and the BDEs 99, 100, 153, 154 and HBCDD. The developmental health outcome parameters in the children studied were aimed at neurological, immunological and reproductive development. A total of 90 mothers and their children were included in the study. Blood withdrawal was at w 20 and w 35 of pregnancy as well as cord blood and child blood at 3 months and at 18 months of age. Investigation of development of the children was performed at 14 days of age, at 3, 10 and 18 months of age.

Conclusions from the human data

The conclusion from the Swedish Fishermen and Fishermen's Wives cohort study are, that the results observed do not support an association between fish born-HPC exposure and bone fracture incidence, or bone mineral density changes. The conclusion from the Groningen Child Development study is preliminary, because the data are still not fully evaluated.

From the data obtained so far, there are at best some weak associations observable between HPC exposure in mothers and some neurological development parameters in the children. In addition, there are some weak associations between maternal HPC exposure and thyroid hormone and sex hormone parameters in boys at 3 months of age. It should be noted however, that the possible influence of confounding factors on these weak associations is not fully evaluated yet.

Integrated and comparative risk assessment

The LOAEL for effects on estrous cycle length in offspring, changes in open field locomotion and decreases in serum TT4 levels were observed at the lowest dose applied of 0,1 mg/kg body weight of 4-OH-CB-107 per day for 7 consecutive days during pregnancy in rats. The serum level of 4-OH-CB-107 in rat offspring from dams from the 0,1 mg/kg exposure group on postnatal day 4 was on average 0,6 µg/gram plasma, or 85,7 µg/g lipid in plasma. Here it is assumed that the HPC plasma concentration on PND 4 is a fair representation of the prenatal plasma level of the offspring, i.e., during the critical window of development of reproductive and neurobehavioural capacity in rats. It is also assumed that the no observable adverse effect level (NOAEL) is about 1/5$_{th}$ of the LOAEL, or at a dose level of 0,02

mg/kg and that the corresponding plasma levels in rat offspring on PND would also be at or around 1/5th of the level observed at the LOAEL dose level, or 0,12 µg /g plasma, or about 17 µg /g lipid in plasma.

When the rat offspring plasma level of 17 µg /g lipid estimated on the basis of a NOAEL exposure level of 0,02 mg/kg is compared to the cord serum levels from the human child development cohort, of on average 7,7 ng/g land a maximal observed level of 22,5 ng/g lipid for 4-OH-CB-107 there is a difference of about a factor 1000. This margin of safety would normally be sufficient to cover the uncertainty in extrapolating from laboratory animals to human individuals.

However, if the individual HPCs (OH-PCBs and PCP) are summed-up, based on similar modes of action on e.g., the thyroid axis, the average concentration in cord serum of total T4-EQ was 2,5 µgT4-EQ/g lipid with a maximal observed concentration of 5,7 µgT4-EQ/g lipid in cord serum. The concentration of T4-EQ estimated to be present in serum from rat offspring at PND 4 from dams exposed to an estimated NOAEL dose of 0,02 mg/kg would be around 220 µgT4-EQ/g lipid, assuming that a linear relationship exists between external exposure and internal serum levels for HPCs in rats. Assuming further that PCP also would produce effects in vivo similar to the hydroxy-PCBs, this would suggest that the margin of safety between experimental animal studies and human individual exposure levels may only be in the order of a factor of 50 when expressing internal exposure levels of HPCs as µgT4-EQ/g lipid. This margin of safety may not be sufficient enough to cover all uncertainty in extrapolation from experimental animals to human infants. This situation is even worse when considering the contaminated sites in Slovakia or the high background exposure area in the Faroe Islands. Plasma concentrations of hydroxylated PCBs were respectively 3-40 times higher and 5-10 times higher than the concentrations in mothers from the Groningen child development cohort. Moreover, PCP was not even determined yet in the Faroe Island, or the Slovakia plasma samples. This would suggest that there is very little margin of safety left in these contaminated areas with respect to possible consequences for reproductive and neurobehavioural development.

The levels of brominated HPCs observed in human adult and infant serum are generally 3-10 times lower than the levels chlorinated HPCs. On the other hand the observed effects of brominated HPCs in experimental animal studies were much less pronounced and required exposure levels of 50 to 250 times higher than of the chlorinated HPCs investigated. Therefore, it is concluded that there is presently sufficient margin of safety for brominated HPCs and that current background exposure levels of human individuals to brominated HPC does not pose any risk for adverse health effects.

In terms of sources of exposure to hydroxylated PCBs it is estimated that the main source of exposure would be the internal production by metabolism of the parent PCB congeners. The possible sources of external exposure are limited to eggs, liver, or liver products, blood, or blood products, due to the specific distribution pattern of hydroxyl-PCBs. However, these external sources are most likely outnumbered by far by the internal production due to metabolism of PCBs. This is certainly not the case for pentachlorophenol (PCP), which is still used as wood preservative in some areas of the world. Exposure to PCP via food and environment will continue to exist for a long time to come. PCP is the dominating contributor to the total T4-EQ as well as the predominant chlorinated HPC present in human serum, i.e.,10 times higher concentration than any of the other chlorinated HPCs present. This pinpoints to a urgency to further investigate exposure and effect levels for pentachlorophenol, as well as options to replace and reduce environmental contamination.

Based on the above risk assessment possible effects in human individuals, in particular in children are not very likely to occur in background exposure situations, like the Groningen Child Development cohort. In fact, the results from this child development study indicate that there are no obvious effects from HPC exposure observable in the children involved in the cohort. There are some findings observed in the Child development study which suggest some weak but significant correlations between HPC exposure and some aspects of endocrine and neurobehavioural development. It should be noted

however, that a proper evaluation of the data and of the possible impact of confounding factors is not completed yet.

Final conclusions

Human individuals are exposed to a mixture of different HPCs, derived from internal (metabolism) as well as external sources. Background exposure levels in human infants to HPCs, when considering individual congeners, suggests that there still is a sufficient margin of safety left to avoid occurrence of adverse developmental health outcome due to these compounds. However, when considering a summing-up of chlorinated HPCs as μgT4-EQ/g lipid in cord serum, there is only a small margin of safety left of about a factor 45 for children born to mothers exposed to background levels of HPCs.. This margin of safety does probably not exist when considering human individuals, in particular children, living in high exposure areas, like Faroe Islands and at contamination sites in Slovakia. In other words, adverse developmental health effects from chlorinated HPCs in human children originating from contaminated, or otherwise high background exposure area cannot be excluded. The results from the Compare study with respect to the brominated HPCs studied do not support that an additional risk for adverse health effects can be expected at current background exposure levels of the brominated HPCs investigated in human individuals.

Benefits and Beneficiaries

The main benefit from the results of the Compare study is the integrated and comparative risk assessment of the chlorinated and brominated halogenated phenolic compounds (HPCs) investigated. It is stressed that this risk assessment provides a preliminary state of the art situation, since evaluation, and interpretation of the Compare datasets is still ongoing. This risk assessment is timely and there is a great need for this information regarding questions about the safety of e.g., brominated chemicals that are presently widely used globally in a wide variety of applications. The main beneficiaries of the Compare study results with respect to the risk assessment performed are national and international regulatory bodies, chemical industry and the general public.

Future Actions

Continuation of the data evaluation and interpretation process of the Compare study results and dissemination of results through e.g., scientific publications outside of the Compare project term.

Partners

N°	Organisation	Country
1	Vrije Universiteit , Institute for Environmental Studies, Amsterdam	Netherlands
2	Universität Düsseldorf, Neuro- und Verhaltenstoxikologie Medizinisches Institut für Umwelthygiene	Germany
3	Stockholm University, Department of Environmental Chemistry	Sweden
4	Uppsala University, Department of Environmental Toxicology	Sweden
5	Lund University, Institute of Laboratory Medicine, Department of Occupational And Environmental Medicine	Sweden
6	State University Groningen, Department of Pediatrics	Netherlands
7	National University of Ireland, Department of Pharmacology, Dublin	Ireland

EDEN –Emerging Diseases in a changing European Environment

GOCE-CT- 2003- 010284

http://www.eden-fp6project.net/

Instrument:	FP6 Integrated Project (IP)	Contract starting date: 1/11/2004
Total project cost:	15.325.900 €	Duration: 60 months
EC Contribution:	11.497.856 €	
Organization:	Centre de Coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), Montpellier, France	
Co-ordinator:	Stéphane de La Rocque (stephane.de_la_rocque@cirad.fr)	
EC Contact person:	Tuomo Karjalainen (tuomo.karjalainen@ec.europa.eu)	

Abstract

In recent years, several vector-borne, parasitic or zoonotic diseases have (re)-emerged and spread in Europe with major health, ecological, socio-economical and political consequences. Most of these outbreaks are linked to global and local changes resulting from climate change, human-induced landscape changes or the activities of human populations. Europe must anticipate, prevent and control new emergences to avoid major societal and economical crises (cf. SARS in Asia, West Nile in the USA). EDEN (Emerging Diseases in a changing European Environment) offers a unique opportunity to prepare for uncertainties about the future of the European environment by exploring the impact of environmental and other changes on human health.

EDEN's aims are to identify, evaluate and catalogue European ecosystems and environmental conditions linked to global change, which can influence the spatial and temporal distribution and dynamics of human pathogenic agents. The project will develop and co-coordinate at the European level a set of generic methods, tools and skills such as predictive emergence and spread models, early warning, surveillance and monitoring tools and scenarios, which can be used by decision makers for risk assessment, decision support for intervention and public health policies both at the EU and at the national or regional level. Part of EDEN's innovation will be to combine spatial data (earth observation data, GIS etc) with epidemiological data.

EDEN has selected for study a range of indicator human diseases that are especially sensitive to environmental changes and will be studied within a common scientific framework (involving Landscapes, Vector and Parasite bionomics, Public Health, and Animal Reservoirs). Some of these diseases are already present in Europe (Tick- and Rodent-borne diseases, Leishmaniasis, West Nile fever), others were present historically (Malaria) and so may re-emerge, whilst others are on the fringes of Europe (Rift Valley Fever) in endemic regions of West and Northern Africa.

EDEN integrates research in 47 leading institutes from 24 countries with the combined experience and skills to reach the project's common goals. EDEN is organised into a series of vertical Sub-Projects led and managed by internationally recognised experts, and linked together by a series of Integrative Activities that include biodiversity monitoring, environmental change detection, disease modelling, remote sensing and image interpretation, information and communication. The proposed management structure, including a Steering Committee and an Advisory Group, takes into account both the diversity of the partners and the size of the project.

The eco-geographical diversity of the project area covers all relevant European eco-systems from polar areas in the North to the Mediterranean basin and its link with West Africa in the South, and from Portugal in the West to the Danube delta in the East.

Partners

N°	Organisation	Country
1	Centre de coopération Internationale en Recherche Agronomique pour le Développement (CIRAD), Montpellier	France
2	University of Utrecht, Utrecht	Netherlands
3	Université Catholique de Louvain, Louvain	Belgium
4	Zoology, Oxford, Oxford	UK
5	European Agro-Environmental Health Associates EEIG – Euro Aegis	
6	Department of Public Health, University La Sapienza, Rome	Italy
7	IZS dell'Abruzzo e del Molise, Terramo	Italy
8	Institut Pasteur Paris, Paris	France
9	Instituto de Salud Carlos III, Madrid	Spain
10	Entente Inter-Départementale pour la Démoustication du littoral méditerranéen, Montpellier,	France
11	Academy of Sciences, Prague	Czech Republic
12	Istituto Superiore di Sanità, Rome	Italy
13	Institut de Recherche pour le Développement, Paris	France
14	Hacettepe University Faculty of Science, Ankara	Turkey
15	Universidade Nova de Lisboa, Lisbon	Portugal
16	Institut National d'Hygiène, Rabat	Morocco
17	Universitat de Valencia, Valencia	Spain
18	Centro di Ecologia Alpina, Viote del Monte Bondone	Italy
19	Medical Academy, Bialystok	Poland
20	Ludwig Maximilians Universitaet Muenchen, Munich	Germany
21	Slovak Academy of Sciences, Bratislava	Slovakia
22	National Health Development Institute, Tallinn	Estonia
23	Medical Faculty of Ljubljana, Ljubljana	Slovenia
24	Instituto Vasco de Investigación y Desarrollo Agrario, Vitoria	Spain
25	"Johan Béla" National Centre for Epidemiology, Budapest	Hungary
26	Public Health Agency, Riga	Latvia
27	Centre for Communicable Diseases Prevention and Control, Vilnius	Lithuania
28	Finnish Forest Research Institute, Helsinki	Finland
29	Institut National de la Recherche Agronomique, Montpellier	France
30	Swedish Institute for Infectious Disease Control, Solna	Sweden
31	University of Antwerp, Anvers	Belgium
32	University of Helsinki, Helsinki	Finland
33	University of Liverpool, Liverpool	UK
34	Natural History Museum, London	UK
35	Ege University Medical School, Izmir	Turkey
36	London School of Hygiene & Tropical Medicine, London	UK
37	Faculty of Veterinary Science, Budapest	Hungary
38	University of Barcelona, Barcelona	Spain
39	Université de Montpellier, Montpellier	France
40	University of Crete, Iraklion	Greece
41	Institut Agro-Vétérinaire, Rabat	Morocco

42	Institut Supérieur de la Recherche Agronomique, Dakar	Senegal
43	National Institute of Research and Development for Microbiology and Immunology "Cantacuzino", Bucharest	Romania
44	Danube Delta National Institute for Research, Tulcea	Romania
45	Consejo Superior de Investigaciones Cientificas, Estacion Biologica de Danona, Sevilla	Spain
46	Pasteur; Alger	Algeria
47	MTA Állatorvos-todományi Kutató Intézete, Department of Viral Vaccines and Pathogenesis, Budapest	Hungary

FAMIZ - Food web uptake of persistent organic pollutants in the arctic marginal ice zone of the Barents Sea

EVK3-CT-2000-00024

http://www.io-warnemuende.de/projects/famiz

Final report: http://ec.europa.eu/research/endocrine/pdf/evk3-ct-2000-00024-final-pr-rep_en.pdf

Instrument:	FP5 Research Project	Contract starting date: 01/12/2000
Total project cost:	624.948 €	Duration: 36 months
EC Contribution:	600.000 €	
Organization:	Stockholm University, Inst of Applied Environmental Research	Stockholm, Sweden
Co-ordinator:	Örjan Gustafsson (orjan.gustafsson@itm.su.se)	
EC Contact person:	Tuomo Karjalainen (tuomo.karjalainen@ec.europa.eu)	

Objectives

The overall objective of FAMIZ was to develop a quantitative understanding of the processes governing the uptake of POPs in the base of the food web in the Arctic marine ecosystems. The limited set of data that was available at the time of the application indicated that the bioaccumulation in this environment is greater than in other ecosystems. Several hypotheses were formulated to address which processes that might be responsible for enhanced bioaccumulation. They focused on either enriched activities in the abiotic ice-associated compartments (from ice-rafted sediments and efficient snow scavenging, and possible locally elevated exposures in microenvironments such as brine channels), or particular characteristics of the sympagic (under ice) food web and/or the pelagic food web in the marginal ice zone as the two most important areas of primary production for the Arctic marine environment.

Scientific achievements

The present study provides the first quality-assured data set of individual PCBs in ice-associated abiotic matrices in the Arctic Ocean. The low ambient levels require specialized ultra-clean procedures to avoid contamination of the samples. Generally, similar trace-level concentrations are found in different ice-associated matrices (snow, ice, IRS, and ice-interstitial melt water. However, there are a few indications that the ice-associated system may have provided higher exposure to PCBs in its different microenvironments earlier in the season than what was generally observed in the bulk of our samples. Hence, while the scenario outlined by the "abiotic" hypotheses could not be confirmed, it can neither be ruled out that locally-elevated exposures at the base of the Arctic food chain do occur at the onset of melting/vegetative season. To test the sympagic bioaccumulation hypothesis, consistent data sets were obtained for PCBs in particulate matter, macroalgae, ice amphipods, and polar cod. These data appeared to be relatively representative for the stations sampled in the MIZ during the Arctic summer. The results indicated that the PCBs bioaccumulated strongly in the lower trophic levels of the sympagic food chain. There was some evidence of biomagnification as documented by increasing bioaccumulation factors with increasing trophic level as measured by δ^{15}N. However, the comparison with theMIZ pelagic food web suggested that the sympagic food web was if anything less efficient at transferring PCBs up towards top consumers. However, since the bioaccumulation in the MIZ pelagic food web was found to be somewhat greater than the bioaccumulation in the Baltic Sea pelagic food web (see Hypothesis 4 on pelagic), we conclude that the "sympagic" hypothesis could make a small contribution to enhanced bioaccumulation in the MIZ.

The comparison of SPM/water bioaccumulation factors indicated that the pelagic bioaccumulation of PCBs in the MIZ was somewhat greater in the Barents MIZ than in the Baltic Sea, and it appeared that this could be related to the colder temperatures. The comparison of the zooplankton/water bioaccumulation factors showed that bioaccumulation was about 3 times greater in the MIZ than in the Baltic at comparable temperatures. Compared to summer conditions in the Baltic Sea, the bioaccumulation in summer in the MIZ was even greater. This was not due to differences in trophic level. Instead, differences in lipid extractability and lipid storage properties for PCBs are likely the cause.

Socio-economic relevance and policy implications

The starting point of this project was the widely held opinion that there is an unusual bioaccumulation of persistent organic pollutants in the base of the Arctic food web that contributes markedly to unusually high levels of these compounds in wildlife in this region and in people who consume this wildlife such as the Inuit. This project demonstrated that this is not the case. The bioaccumulation in the MIZ food web was similar to that in a comparable food web in the Baltic Sea. This means that indigenous peoples such as the Inuit are not being exposed to high concentrations for this reason. Consequently, the high levels in the food web can be clearly attributed to the high levels of the chemicals in the marine environment. This allows management strategies to address this problem to be more effectively targeted, thereby contributing to the mitigation of the social and health costs of persistent organic pollutants in the Arctic. A further economic benefit of this work is that it shows that the Barents Sea fishery is not subject to a uniquely high bioaccumulation of contaminants. The contaminant bioaccumulation behaviour is similar to in other fisheries. Therefore the economic value of the fishery is not threatened by this problem as had been feared.

Conclusions

This project has yielded a much more differentiated picture of bioaccumulation in the Arctic than what was previously available. It would appear that there is no enhanced bioaccumulation of the higher chlorinated congeners in the lower food web, in contrast to the current belief. There is however an enhanced bioaccumulation of the lower chlorinated congeners, but the enhancement – at most a factor of 5.5 – is less than expected. Some of this enhancement can be attributed to the colder temperatures increasing the partitioning tendency of the PCBs from water into organic material. The remainder has yet to be explained, but there were some indications that elevated ice-associated exposures may occur early on in the vegetative (melting) season.

Dissemination of results

The new knowledge gained in this project will be made publicly available in the form of manuscripts in high-impact peer-reviewed scientific journals.

Keywords

Arctic, plankton, PCB, ice, bioaccumulation

Partners

N°	Organisation	Country
1	Stockholm University, Institute of Applied Environmental Research	Sweden
2	Institut für Ostsseeforschung Warnemünde, Rostock	Germany
3	University of Tromsø	Sweden

FIRE - Risk assessment of brominated flame-retardants as suspected endocrine disrupters for human and wildlife health

QLK4-CT-2002-00596

http://www.rivm.nl/fire

Instrument:	FP5 Research Project	Contract starting date: 01/12/2002
Total project cost:	6.811.999 €	Duration: 48 months
EC Contribution:	4.862.885 €	
Organization:	National Institute for Public Health and the Environment (RIVM)	Bilthoven, Netherlands
Co-ordinator:	Antoon Oppenhuizen (a.opperhuizen@rivm.nl)	
EC Contact person:	Tuomo Karjalainen (tuomo.karjalainen@ec.europa.eu)	

Objectives

The overall objective of this multi- and interdisciplinary project is to improve risk assessment of brominated flame retardants (BFRs) for human health and wildlife. BFRs, such as the high production volume chemicals polybrominated diphenyl ethers (PBDEs), tetrabromobisphenol A (TBBPA) and hexabromocyclododecane (HBCDD) have been identified as potential endocrine disrupters. PBDE levels have been steadily increasing in biota over the last decades. Using in vitro cell systems of particular relevance for endocrine effects, BFRs will be selected for rodent and fish toxicity studies with emphasis on endocrine and immune system. After further selection, reproduction studies in the rat (with neurobehavioral and immune function tests) and partial life-cycle assays in zebrafish will be carried out. The exposure part includes congener specific identification, regional distribution and temporal trends of BFRs in tissue of wildlife and fish, human milk and diet within the EU. By integrating information on exposure, fate and toxicity this project aims a highly significant contribution to integrated risk assessment for humans and aquatic environment with respect to endocrine disruption by BFRs.

Scientific approach

Prescreening of BFRs

For the prescreening of BFRs a battery of in vitro assays (human, rat and fish cell lines, WP2) and QSAR models (WP1) will be used, to: i) determine the endocrine disrupting potency; ii) to select the test compounds for testing in in vivo studies; and iii) to determine the appropriate test concentrations for in vivo studies (WPs 3, 4). TBBPA will be included as in vitro assays have shown that this compound can be a potent competitor with thyroxin for its plasma carrier protein transthyretin (TTR). The results of the prescreening study will also be used for the exposure assessment studies to define the compounds that will be determined in the human and aquatic wildlife samples.

Human and wildlife hazard identification and dose-response assessment

Based on the evaluation of the results of the prescreening study, WPs 3 and 5 will concentrate on the human hazard identification and dose-response assessment of the selected BFRs. A 2-generation reproduction study with rats (WP3) will be performed, including TBBPA. Information on the histopathology, sex steroidgenesis, thyroid activity, immune function, hepatic P450 enzymes, endocrine mediated neurobehavioral function, measurements of whole body and/of target tissues will be collected in the rat study (WP3).

In addition, the toxicokinetics of TBBPA will be studied in human volunteers, and physiologically-based pharmacokinetic (PBPK) modelling applied for humans and rats (WP5), because it is expected that the biliary elimination toxicokinetics of TBBPA may differ between rats and humans. Because of relatively rapid excretion, low toxicity and lack of genotoxicity, TBBPA will be administered to humans in low doses. Toxicokinetics are important determinants for endocrine disrupting activity, since they determine the amount of compound available for binding to the respective receptors and thus for biological responses. Moreover, metabolites formed by various biotransformation reactions may have increased or reduced receptor affinity. Therefore, toxicokinetic data are relevant for inclusion into the risk assessment process for endocrine disrupters.

For the aquatic wildlife hazard identification and dose-response assessment (WP4), the in vivo endocrine disrupting effects of the selected test BFR compound will be studied in a freshwater lower vertebrate model species (zebrafish) as well as in an estuarine wildlife species (flounder), a common indicator species in monitoring programmes. A rapid assay with transgenic reporter zebrafish will be used for the range finding tests before the start of a partial life-cycle assay with zebrafish (compounds selected following subacute testing). In this assay reproduction function will be assessed by fecundity and fertility parameters. In the flounder study the chronic effects of BFRs on endocrine and health status of adult fish at environmentally relevant concentrations will be investigated, after range finding tests have been performed. Fish studies include histopathology, with emphasis on endocrine and immune system, and measurements of whole body and/of target tissues. In the flounder steroid hormone and metabolism will also be investigated, and in the zebrafish a subsample will be used for toxicogenomic analysis as a potential new tool for hazard identification.

Human and aquatic wildlife exposure assessment

Human and aquatic wildlife exposure assessment will be studied in various European countries with different levels of BFRs exposure. To evaluate present and past human exposure to BFRs, composite food samples will be analysed (Czech Republic, The Netherlands, and Norway). To determine human body burdens of BFRs, breast milk (Czech Republic, The Netherlands, and Norway) and serum samples (Norway only) will be investigated (WP6). These countries were selected on the basis of different food consumption patterns (respectively low, medium and high consumption of fishery products) and levels of BFR contamination. In addition, temporal trends of human BFR exposure will be investigated in duplicate diets from 1978, 1984-1985 and 1994, and in serum samples from a time period of 20 years (WP6).

For the aquatic wildlife exposure assessment (WP7, 8, 10), information will be obtained on i) the food chain transfer of BFRs from water, sediment to invertebrates to predators (fish) and fish-eating top-predators (tern, seal and polar bear), ii) temporal trends, iii) environmental transformation (WP8). A predictive food web model will be developed (WP10). For the food chain transfer (WP7) samples will be collected at different levels of BFR pollution exposure in the marine environment, estuaries and freshwater locations. Reference sites will be Arctic and Froan (Norway) and more polluted locations will include The Netherlands (close to a BFR production plant as well as the Wadden Sea), UK (Clyde and Mersey), France (Seine estuary), Germany (Elbe) and Czech Republic (Elbe). BFRs (e.g. PBDEs, HBCD and TBBPA) will be determined and an interlaboratory study will be conducted between the laboratories that perform the BFRs analysis. Temporal trends of BFRs in aquatic wildlife will be investigated using harbour seal samples of a time period of the last 10 years, and dated sediment cores collected in one area of the fish-eating bird species (WP 7). In WP8 environmental transformation reactions of BFRs in the abiotic system (UV-irradiation) and biotic system (micro-organisms and microsomal systems of fish, birds, and marine mammals (e.g., harbour seals) will be studied. On the basis of the aquatic food chain transfer and environmental transformation data, a predictive food web model of BFRs in abiotic environment to the top-predators will be developed (WP10). WP9 is strongly linked to both human (WP6) and aquatic wildlife exposure (WP7, 8) and should provide information on

the contribution of the levels of BFRs from human and wildlife samples to the total in vitro endocrine disrupter response.

Integrated risks assessment for humans and aquatic wildlife

Work package 11 will bring all information together for an integrated, comparative risk assessment of BFRs for human and aquatic wildlife. The integrated risk assessment combines the results on hazard identification, dose-response assessment and exposure assessment leading to risk characterisation. Risks of BFRs to ecological and human endpoints, the variability and uncertainty of these risks will be estimated, and is the input for the dissemination of results and risks in WP 12. The results of the hazard identification, dose-response assessment, exposure assessment, and risk characterisation will be compared with the EU risk assessments carried out under Reg. 793/93.

Dissemination and Cluster Activities

Finally, all information acquired during the FIRE project will be disseminated by Internet, newsletter and brochures via the CREDO cluster (http://www.credocluster.info/). In addition, results are disseminated by publication in scientific papers, and by a workshop (WP12) organised for legislation authorities, industries (CEFIC, BSEF), NGOs (green institutes, e.g. WWF), EU, IPCS, OECD, MEDPOL, ICES, OSPARCOM and HELCOM at month 42. A cluster workshop on exposure assessment was organised in 2005 (http://www.credocluster.info/workshop.html).

Partners

N°	Organisation	Country
1	RIVM - National Institute for Public Health and the Environment, Bilthoven	Netherlands
2	University of Utrecht, Institute for Risk Assessment Sciences (IRAS)	Netherlands
3	Vrije Universiteit, Institute for Environmental Studies, Amsterdam	Netherlands
4	National Institute for Coastal and Marine Management (RIKZ), Middelburg	Netherlands
5	Netherlands Institute for Fisheries Research (RIVO), Ijmuiden	Netherlands
6	Stockholm University, Department of Environmental Chemistry	Sweden
7	University of Würzburg, Department of Toxicology	Germany
8	Ruhr Universität Bochum, Forschungs Institut für Arbeitsmedizin	Germany
9	Norwegian School of Veterinary, National Veterinary Institute, Oslo	Norway
10	Norwegian Institute of Public Health, Division of Environmental Medicine, Oslo	Norway
11	Institute of Chemical Technology, Department of Food Chemistry and Analysis, Prague	Cezch Republic
12	University of Surrey, School of Biomedical and Life Sciences	UK
13	Umea University, Department of Chemistry	Sweden
14	University of Kaiserslautern, Food Chemistry & Environmental Toxicology	Germany
15	Karolinska Institutet, Department of Cell and Molecular Biology, Stockholm	Sweden
16	Norwegian University of Science and Technology, Department of Zoology, Trondheim	Norway
17	The Netherlands Institute for Sea Research, Dept. Marine Biogeochemistry & Toxicology, Den Burg	Netherlands
18	University of Amsterdam, Dept. Environmental & Toxicological Chemistry	Netherlands
19	University of Antwerp, Department of Biology, Research Group for Ecophysiology, Biochemistry and Toxicology	Belgium

INUENDO - Biopersistent organochlorines in diet and human fertility. epidemiologic studies of time to pregnancy and semen quality in inuit and european populations

QLK4-CT-2001-00202

http://www.inuendo.dk

Final report: http://ec.europa.eu/research/quality-of-life/ka4/pdf/report_inuendo_en.pdf

Instrument:	FP5 Research Project	Contract starting date: 01/01/2002
Total project cost:	1.977.959 €	Duration: 42 months
EC Contribution:	1.745.000 €	
Organization:	Aarhus University Hospital	Aarhus, Denmark
Co-ordinator:	Jens Peter Bonde (jpbon@akh.aaa.dk)	
EC Contact person:	Tuomo Karjalainen (tuomo.karjalainen@ec.europa.eu)	

Objective and methods

The Inuendo project addressed reproductive toxicity of dietary persistent organochlorine pollutants (POPs). Couple fertility and male reproductive function were investigated in four regions, Greenland, Sweden, Warsaw and Kharkiv. Pregnant women and their partners were consecutively enrolled during antenatal visits except for Swedish fishermen and their partners who were recruited separately. Time-to-pregnancy interviews were obtained from 2,269 women, blood was sampled in 1992 women and 1172 men, and a subset of 798 men provided a fresh semen sample. Serum concentrations of an indicator of polychlorinated biphenyls (PCBs) [2,2´,4,4´,5,5´-hexachlorobiphenyl (CB-153)] and 1,1-dichloro-2,2-bis (pchlorophenyl)-ethylene (DDE) were measured in both genders. Xenobiotic transactivation of the oestrogen (ER), androgen (AR) and aryl hydrocarbon (AhR) receptor was measured ex-vivo by CALUX assays in a subset of 362 men. Male reproductive function was evaluated by reproductive hormones in blood and a range of sperm characteristics (count, morphology, motility, chromatin and DNA integrity, pro- and anti-apoptotic markers and Y/X chromosome ratio) together with biochemical markers of the epididymal and the accessory sex gland function.

Exposure levels

The median serum concentrations of CB-153 and DDE in the four regions were spanning more than one order of magnitude. Agonistic and competitive xenobiotic transactivation of the ER, AR and AhR differed between regions. Antagonism of the ER and competitive enhancement of the AR resulting in a xenobiotic ER/AR-balance towards higher androgenicity was seen to a higher extent among Inuits than in the European regions. Agonistic AhR transactivation was detected in almost all samples. Median 2,3,7,8-tetrachlorodibenzo-p-dioxin toxic equivalents (TCDD TEQ) values, based on the functional assay, ranged from 200 pg/g lipid among Inuits to 310-430 pg/g lipid in the other regions. Inuit samples exhibited high competitive enhancement of the AhR while the European groups exhibited high AhR competitive antagonism. The xenobiotic receptor activities were not or weakly related to the selected POP markers.

Consistent and coherent corroborating results

Male and female serum concentrations of POPs were related to reduced fertility among Inuit couples. In all regions decreasing progressive sperm motility with increasing CB-153 serum concentrations was

observed. Similar associations between CB-153 and neutral-α- glucosidase point to post-testicular effects on epididymal function that may explain reduced sperm motility. Effects were most pronounced in men with CB-153 blood levels exceeding current levels in the general European population, but the data demonstrated no clear no-effect threshold. In addition, the study revealed a remarkable high level of sperm chromatin integrity and low level of sperm DNA damage among Inuit men that may explain why Inuits may escape the rather strong PCB related effect on sperm chromatin found among Caucasian men.

Consistent refuting results

Serum concentrations of DDE and xenobiotic steroid receptor activities were not related to female and male fertility. Furthermore, blood levels of POP markers and xenobiotic receptor activities in serum were not related to sperm count and morphology and no evidence was found that CB-153 and DDE interfere with the regulation of sperm apoptosis.

Other findings

The study revealed several associations between blood levels of POP markers and male reproductive hormones as well as Y/X sperm chromosome ratio but strong heterogeneity between regions complicates the interpretation. Some associations may be related to heterogeneous exposure profiles and others may appear because of multiple comparisons, confounding or artefacts of the study design. The analyses of hormone-like compounds extracted form the serum of the study subjects' revealed relations between xeno-hormone activity and DNA damages and the anti-apoptotic factor Bcl-xL, whereas only few relations involved the proapoptotic marker Fas.

Conclusions

The study indicates that POPs in the male adult may interfere with his reproductive function without major impact on fertility or sperm counts in European populations. PCBs seem more to blame than DDT. No-effect thresholds cannot be established. Findings provide limited direct evidence that xenobiotic disruption of endocrine regulation is at stake but do not exclude mechanisms related to receptor functions. The study does not address effects of foetal and childhood exposures.

Partners

N°	Organisation	Country
1	Aarhus University Hospital, Department of Occupational Medicine, Aarhus	Denmark
2	University Hospital, Department of Occupational and Environmental Medicine, Lund	Sweden
3	ENEA – Section of Toxicology and Biomedical Sciences, Rome	Italy
4	Università di Modena e Reggio Emilia, Reggio Emilia	Italy
5	National Institute of Hygiene, Department of Environmental Toxicology, Warsaw	Poland
6	Kharkiv State Medical University, Problem Laboratory of human reproductology, Kharkiv	Ukraine
7	Malmö University Hospital, Scanian Andrology Center, Fertility Centre, Malmö	Sweden
8	Aarhus University, Department of Environmental and Occupational Medicine, Aarhus	Denmark

3. Natural Hazards

GLACIORISK - Survey and prevention of extreme glaciological hazards in European mountainous regions

EVG1-CT-2000-00018

http://glaciorisk.grenoble.cemagref.fr

Instrument:	FP5 Research Project	Contract starting date: 01/01/2001
Total project cost:	1.325.509 €	Duration: 36 months
EC Contribution:	647.624 €	
Organization:	CEMAGREF, Etna	St. Martin d'Hérès, France
Co-ordinator:	Michel Gay (michel.gay@cemagref.fr)	
EC Contact person:	Marta Moren Abat (marta.moren-abat@ec.europa.eu)	

Objectives

The main objective of this project was to develop scientific studies for detection, survey and prevention of future glacial disasters in order to save human lives and to reduce damages.

Scientific achievements

A first specific objective was therefore to make a comprehensive inventory of the past catastrophic events related to the glacial environment in the Alps and in the Nordic countries. The six countries concerned in priority are France, Switzerland, Italy and Austria in the Alps, Norway and Iceland in Northern Europe.

The studied natural hazards are:

- Glacier lake outburst floods (GLOF)
- Jökulhlaups (sudden draining of internal water pockets)
- Stability of steep glaciers
- Snow or ice avalanches triggered by serac falls
- Length change of glaciers (creation of temporary dams for instance)

Among the potentially dangerous sites recorded in an exhaustive and updated inventory realised at the beginning of the project, some field sites representative of each glacial hazard have been selected and equipped to conduct various field surveys. For each type of risk, different possible technologies and methods have been specified, then studied and tested. On the basis of these field investigations and of existing models for landslides or dam breaking, numerical models have been developed in order to simulate the processes and to better understand the triggering mechanisms.

Main deliverables

- **D1**: GRIDABASE data base gathering all the information and data concerning the different glacial hazards
- **D2**: Atlas consisting of maps and general information (localisation, type of glacial risk, occurrence of the phenomenon, involved volumes, etc.)
- **D3**: guideline of advice for conducting scientific studies about the various glacial hazards
- **D4**: permanent monitoring of the most representative glaciers which will be interesting to keep even after the end of the project.
- **D5**: numerical simulation of the potentially affected areas on every dangerous site.

- **D6**: some examples of maps showing the risk zoning of a few selected sites, available for end-users, as an experimentation to see whether risk zoning is realistic for glacial hazards.
- **D7**: guideline for prevention and mitigation of the identified glacial hazards, available for end-users.
- **D8**: educational film dealing with glacial hazards
- **D9**: expert evaluation skill gained by each partner on specific glacial risk and exportable to other countries which have to face glacial hazards.

Socio-economic relevance and policy implications

The main socio-economic objective is the improvement of safety. Glacial risks threaten economic targets such as buildings, villages, roads, highways, railways and footpaths. A better understanding of those risks, a systematic survey and appropriate mitigation of risk should reduce the damaging consequences of future disasters. European scientists are consulted as experts for problems in South America or Asia and the increase of skill will help with a better dissemination of European knowledge.

Conclusions

Glacial risks threaten economic targets such as buildings, villages, roads, highways, railways and footpaths. The results of the scientific studies of GLACIORISK project allow a better understanding of those risks. The availability of the glacial risk data base GRIDABASE, of atlas, and of guidelines for scientific studies and for risk prevention and mitigation might help the scientists as well as the concerned end-users in order to take the right decisions for safety.

Dissemination of results

- GRIDABASE data base on risky glaciers, open to everybody on Internet
- Publication of national Atlas and their diffusion to end-users in each country.
- Elaboration and diffusion of guidelines (advice for conducting scientific studies, guidelines for the assessment of glacier risks and for the safety measure evaluation)
- Elaboration and diffusion of an educational film
- Exchange and exportation of expertise
- Scientific publications

Keywords

Glaciers, outburst, mountain lake, ice avalanche, natural hazards

Partners

N°	Organisation	Country
1	CEMAGREF, St. Martin d'Hérès	France
2	ETNA, Unit Erosion Torrentielle, Neige et Avalanches	France
3	Office National des Forêts, Restauration des Terrains en montagne	France
4	CNRS – Laboratoire de Glaciologie et Géophysique de l'Environnement	France
5	Consiglio Nazionale delle Ricerche	Italy
6	Società Meteorologica Subalpina	Italy
7	University of Oslo, Department of Physical Geography	Norway
8	Norwegian Water Resources and Energy Directorate	Norway
9	University of Iceland	Iceland
10	University of Salzburg, Geography Institute	Austria
11	Swiss Federal Institute of Technology, Zürich	Switzerland

4. Natural Resources

EUR-OCEANS - EURopean network of excellence for OCean Ecosystems ANalysis

GCE - 3.3. 511106

http://www.eur-oceans.eu/

Instrument:	FP6 Network of Excellence (NoE)	Contract starting date: 01/01/2005
Total project cost:	40.000.000 €	Duration: 48 months
EC Contribution:	10.000.000 €	
Organization:	Centre National de la Recherche Scientifique (CNRS), France	
Co-ordinator:	Paul Tréguer (paul.treguer@univ-brest.fr)	
EC Contact person:	Christos FRAGAKIS (Christos.Fragakis@ec.europa.eu)	

Abstract

EUR-OCEANS aims to achieve lasting integration of European research organisations on global change and pelagic marine ecosystems, and to develop models for assessing and forecasting the impacts of climate and anthropogenic forcing on food-web dynamics (structure, functioning, diversity and stability) of pelagic ecosystems in the open ocean. The NOE will favour the progressive integration of research programmes and facilities of major research Institutes all over Europe. The long-term goal of the NOE is to create a multi-site Institute for European Research on Ocean Ecosystems under anthropogenic and Natural forcings. The international context is provided by Global Ocean Ecosystem Dynamics (GLOBEC), and the forthcoming Integrated Marine Biogeochemistry and Ecosystem Research (IMBER) of the International Geosphere Biosphere Programme (IGBP).EUR-OCEANS' Joint Programme of Activities (JPA) comprises:

1. Integrating activities on: networking (data and model integration);
2. Jointly executed research, organised around four broad modelling tasks (together with observations and experiments) on: pelagic ecosystems end-to-end, biogeochemistry, ecosystem approach to marine resources and within-system integration;
3. Activities to spread excellence, including training of researchers, and spreading excellence to socio-economic users and to the European public (through the Association of Aquaria for EUR-OCEANS public outreach);
4. Management Activities. Administrative and Financial Coordinator: Institut Océanographique. Governing bodies: General Assembly (Member Organisations); Executive Committee (incl.Scientific Director and the Deputy); Steering Committee (incl. Work Packages Leaders). Councils: Scientific, Intellectual, Gender Equality, and EUR-OCEANS Institute. Composition: 69 Member Organisations, from 25 states (incl. 7 Third countries); 160 PIs selected for their capacity and excellence. Close cooperation with the USA, Australia, Canada, Namibia and Japan.

Partners

N°	Organisation	Country
1	Centre National de la Recherche Scientifique (CNRS)	France
2	Institut des Sciences de la Mer et de l'Aménagement du Littoral (ISMAL)	Algeria
3	Vrije Universiteit Brussel (VUB)	Belgium
4	Université Catholique de Louvain (UCL-ASTR)	Belgium
5	Université Libre de Bruxelles (ULB)	Belgium
6	Université de Liège (ULg)	Belgium

7	Centro de Investigación Oceanográfica en el Pacifico Sur-Oriental Universidad de Concepcion (COPAS)	Chile
8	Danish Institute for Fisheries Research (DIFRES)	Denmark
9	National Environmental Research Institute (NERI)	Denmark
10	University of Aarhus (UAAR)	Denmark
11	Tartu Uelikool, Eesti Mereinstituut (MEI)	Estonia
12	Finnish Institute of Marine Research (FIMR)	Finland
13	France Innovation Scientifique et Transfert (FIST S.A.)	France
14	Commissariat à l'Energie Atomique (CEA)	France
15	Institut de Recherche pour le Développement (IRD)	France
16	Institut Français de Recherche pour l'Exploitation de la MER (Ifremer)	France
17	SOPAB-BREST (Océanopolis)	France
18	Alfred-Wegner Institut für Polar- und Meeresforschung (AWI)	Germany
19	Leibniz- Institut für Meereswissenschaften (IFM-GEOMAR)	Germany
20	Institut für Ostseeforschung Warnemünde (IOW)	Germany
21	Max-Planck-Gesellschaft zur Förderung der Wissenschaften (MPG)	Germany
22	Universität Hamburg (Uni-HH)	Germany
23	Universität Bremen (Uni-HB)	Germany
24	Hellenic Centre for Marine Research (HCMR)	Greece
25	Consiglio Nazionale delle Ricerche (CNR-IAMC)	Italy
26	Consorzio Nazionale Interuniversitario per le Scienze del Mare (CoNISMa)	Italy
27	Istituto Nazionale di Geofisica e Vulcanologia (INGV)	Italy
28	Istituto Nazionale di Oceanografia e di Geofisica Sperimentale (OGS)	Italy
29	Stazione Zoologica 'A. Dohrn' (SZN)	Italy
30	Latvian Fish Resources Agency (LATFRA)	Latvia
31	Institut National de Recherche Halieutique (INRH)	Morocco
32	Rijksuniversiteit Groningen (RuG)	Netherlands
33	Nederlands Instituut voor Ecologie (NIOO)	Netherlands
34	Universiteit van Amsterdam (UvA)	Netherlands
35	Wageningen Universiteit, Department Environmental Sciences (WU)	Netherlands
36	Royal Netherlands Institute for Sea Research (NIOZ)	Netherlands
37	Universitetet i Tromsoe (UiT)	Norway
38	Norwegian Polar Institute (NPI)	Norway
39	Norwegian University of Science and Technology (NTNU)	Norway
40	Universitetet i Bergen (UiB)	Norway
41	Havforsksningsinstituttet (IMR)	Norway
42	Institute of Oceanology Polish Academy of Sciences (IO PAS)	Poland
43	Sea Fisheries Institute (SFI (MIR))	Poland
44	Instituto Nacional de Investigação Agrária e das Pescas (INIAP-IPIMAR)	Portugal
45	P.P. Shirshov Institute of Oceanology, Russian Academy of Sciences (SIO)	Russia
46	University of Cape Town (UCT)	South Africa
47	FUNDACIÓN AZTI - AZTI FUNDAZIOA (AZTI)	Spain
48	Consejo Superior de Investigaciones Cientificas (CSIC)	Spain
49	Instituto Español de Oceanografia (IEO)	Spain
50	Universidad de Las Palmas de Gran Canaria (ULPGC)	Spain
51	Universidad de Vigo (UVIGO)	Spain
52	Naturhistoriska riksmuseet (Swedish Museum of Natural History) (NRM)	Sweden
53	Göteborg University (UGOT)	Sweden
54	Stockholms Universitet (USTOCK)	Sweden
55	University of Bern (UNIBE)	Switzerland

56	Faculty of Science of Bizerta (FSB)	Tunisia
57	Middle East Technical University, Institute of Marine Sciences (IMS-METU)	Turkey
58	Institute of Biology of the Southern Seas (IBSS)	Ukraine
59	University of Essex (UESSEX)	UK
60	Natural Environment Research Council (NERC)	UK
61	The Centre for Environment Fisheries and Aquaculture Science (CEFAS)	UK
62	Plymouth Marine Laboratory (PML)	UK
63	University of Southampton (USOU)	UK
64	University of Warwick (Warwick)	UK
65	The Scottish Ministers Acting Through Fisheries Research Services Marine Laboratory	UK
66	Imperial College of Science, Technology and Medicine (ICL)	UK

HERMES - Hotspot Ecosystem Research on the Margins of European Seas

511234

http://www.eu-hermes.net/

Instrument:	FP6 Integrated Project (IP)	Contract starting date: 01.04.2005
Total project cost:	21.828.715 €	Duration: 48 months
EC Contribution:	14.999.974 €	
Organization:	National Oceanography Centre Southampton	UK
Co-ordinator:	Prof. Philip P.E. Weaver (ppew@noc.soton.ac.uk)	
EC Contact person:	Teresa CUNHA (Teresa.CUNHA@ec.europa.eu)	

Abstract

HERMES is designed to gain new insights into the biodiversity, structure, function and dynamics of ecosystems along Europe's deep-ocean margin. It represents the first major attempt to understand European deep-water ecosystems and their environment in an integrated way by bringing together expertise in biodiversity, geology, sedimentology, physical oceanography, microbiology and biogeochemistry, so that the generic relationship between biodiversity and ecosystem functioning can be understood. Study sites will extend from the Arctic to the Black Sea and include open slopes, where landslides and deep-ocean circulation affect ecosystem development, and biodiversity hotspots, such as cold seeps, cold-water coral mounds, canyons and anoxic environments, where the geosphere and hydrosphere influence the biosphere through escape of fluids, presence of gas hydrates and deep-water currents. These important systems require urgent study because of their possible biological fragility, unique genetic resources, global relevance to carbon cycling and possible susceptibility to global change and man-made disturbances.

Past changes, including catastrophic events, will be assessed using sediment archives. We will make estimates of the flow rates of methane from the geosphere and calculate how much is utilised by benthic communities, leaving the residual contribution to reach the atmosphere as a greenhouse gas. HERMES will enable forecasting of biodiversity change in relation to natural and man-made environmental changes by developing the first comprehensive pan-European margin Geographic Information System. This will provide a framework for integrating science, environmental modelling and socio-economic indicators in ecosystem management. The results will underpin the development of a comprehensive European Ocean and Seas Integrated Governance Policy enabling risk assessment, management, conservation and rehabilitation options for margin ecosystems.

Partners

N°	Organisation	Country
1	NERC/National Oceanography Centre Southampton	UK
2	IFREMER	France
3	Royal NIOZ	Netherlands
4	University of Barcelona	Spain
5	Hellenic Centre for Marine Research	Greece
6	IFM-GEOMAR	Germany
7	CNR-ISMAR	Italy

8	Alfred Wegner Institute	Germany
9	University of Tromsø	Norway
10	National University of Ireland Galway	Ireland
11	University of Erlangen	Germany
12	University of Gent	Belgium
13	CSIC	Spain
14	CoNISMa	Italy
15	Max Planck Institute	Germany
16	CNRS-CEFREM	France
17	Instituto Hidrografico	Portugal
18	International University Bremen	Germany
19	University of Bremen	Germany
20	University of Wales, Cardiff	UK
21	Institute of Marine research, Bergen	Norway
22	University of Goteborg	Sweden
23	University of Southampton	UK
24	The National Institute of Oceanography and Applied Geophysics (OGS)	Italy
25	University of Birmingham	UK
26	Netherlands Institute for Ecology	Netherlands
27	University of Aberdeen	UK
28	University of Liverpool	UK
29	DEU Institute of Marine Science and Technology	Turkey
30	Scottish Association for Marine Science	UK
31	University of Aveiro	Portugal
32	GeoEcoMar	Romania
33	Intergovermental Oceanographic Commision/UNESCO	
34	University of Pierre and Marie Curie	France
35	University Bretagne Occidentale	France
36	Institut Scientifique Rabat	Morocco
37	Challenger Oceanic, Surrey	UK
38	Volcanic Basin Petroleum Research, Oslo	Norway
39	Praesentis, Barcelona	Spain
40	Median	Spain
41	MMCD, Düsseldorf	Germany
42	Olex AS, Trondheim	Norway
43	ArchimediX, Ober-Ramstadt	Germany
44	Proteus, Nîmes	France
45	Jobin Yvon	Spain

IRIS - Ice ridging information for decision making in shipping operations

EVK3-CT-2002-00083

http://www.tkk.fi/Units/Ship/Research/Iris/Public/

Instrument:	FP5 Research Project	Contract starting date: 01/01/2003
Total project cost:	3.166.168 €	Duration: 36 months
EC Contribution:	2.008.432 €	
Organization:	Helsinki University of Technology, Finland	
Co-ordinator:	Kaj Riska (kaj.riska@hut.fi)	
EC Contact person:	Mr. Witold CIESLIKIEWICZ (witold.cieslikiewicz@ec.europa.eu)	

Abstract

The IRIS project has been carried out at the Community level because the monitoring of sea areas is by definition an international activity. The public services in European countries with harsh marine climate need to co-operate in supporting the safety of ship transport, fisheries and other marine activities. Of particular concern is sea ice which is present in the Baltic Sea and the Arctic Ocean, including the Barents Sea. Sea ice monitoring and related services (e.g. icebreaker operations) are expensive and international co-operation is essential. The EC infrastructure support given to the Baltic icebreaker services is an example of this. The development work addressed in IRIS has been carried out most effectively in a joint European project by a group of institutes with expertise in ship technology, sea ice research and oceanography, remote sensing, communication and computer science.

The benefits of involving several countries are that the service developed is applicable on European level instead of only on national level and that standardization of products and transmission methods can be achieved. Moreover, the reliability of the information is strongly dependent on the observational network of each country: observations from coastal stations, icebreakers and commercial ships and from survey flights. The development must be based on cooperation between the national ice services.

The scientific motivation of IRIS has been to include new innovations in ice cover description to ice information. This is most efficient when the ice services use the same format of presentation. For ice charts this is realised if one charting application is used, as then new features can be added by upgrading the application. This way the digitally delivered ice information from ice services can be viewed on board with an appropriate terminal.

The Baltic Sea has been used as a validation area for the new developments in IRIS. In the Baltic the whole chain from ice information production to end users has been easily accessible. The development of ice information systems in other sea areas, especially in the Eurasian Arctic, will be based on the Baltic state-of-the-art. In a longer run the main application of the developed methods will be in these areas, because in the Eurasian Arctic, especially along the Northern Sea Route, profitable maritime transport will be based on navigation by ice strengthened merchant vessels. For such operations reliable ice information and optimal route selection are essential.

Demand on increased unassisted navigation, enabling more effective execution of icebreaker operations, will continue in the Baltic. In addition to further enhancements in standard ice information, delivered free-of-charge to all users, the demand of ice customised information will increase. Thus, similarly to the recent developments of weather forecasting, there is a fertile soil for commercial enterprises,

providing detailed local ice conditions and ship specific trafficability forecasts. These might operate in the Baltic with some support from governmental ice services. In the Eurasian Arctic a commercial ice service, based on satellite images and focusing on each navigating ship, is a realistic alternative. Such service emerges most feasibly from the Baltic knowhow.

IRIS is especially relevant for the following EU policies:

- Sea transport: IRIS contributes to safer and more cost-effective sea transport in the Baltic Sea and the European Arctic waters. Ship traffic on the Northern Sea Route, which is increasing when Europe starts to utilise the Russian northern energy reserves, will require the best possible monitoring and forecasting service in order to be a technically and environmentally safe and useful sailing route.

  IRIS serves the objectives of the Common Transport Policy and national transport policies by implementing sustainability in the long-term balance between the growing demand for mobility and the necessity to respect environmental, safety, social and economical constrains. It increases the quality of met-ice-ocean information by building a tool for cost-effective support of marine transport operations. IRIS also contributes to increased safety of sea transport by providing user-friendliness in operational data at an affordable cost for individual users and the society in general.

  The winter-time ship traffic in the Baltic Sea is significant: annually more than 0.5 billion tons of cargo is transported by sea of which over 40% during winter months. This means tens of thousands port-calls for ships going through ice. Considerable economic savings can be achieved by optimising ice navigation and reducing transit times. With better access to ice information products the risks for ship damages and accidents, being always present in ice navigation, will be reduced. Better ice information will also decrease the risks involved with winter navigation. In addition to the prevention of damage and loss of life this will result into increased environmental safety.
- Fisheries: The north-east Atlantic, including Greenland and Icelandic waters, the Barents Sea and other Arctic ice edge regions provide 20% of the world's fish catch, with many of the leading fishing nations being EU members and EEA members. These ocean areas have rough weather and ice, which require good monitoring and forecasting services for the fishing vessels. The results of IRIS can contribute to several elements of CFP, such as provide databases from which scientists can study ocean parameters relevant for fisheries near marginal ice zone.
- Energy resource exploitation: Improved observation and prediction of weather, sea ice and ocean conditions is necessary for operations associated with exploration and exploitation of hydrocarbon resources on in ice covered waters like the Barents Sea and on the Siberian shelf seas. The dimensioning of offshore platforms requires the estimation of long-term maximal ice loads. When production of oil and gas start in these regions, there will a considerable increase in sea transportation as well. The rapid increase in the volumes of oil transportations from the Russian port of Primorsk has been a clear evidence of this development.
- Environmental policies and treaties: IRIS is relevant for several aspects of EU's environmental policy by contributing to safer operations in marine and Arctic environments, which are vulnerable to pollution and other impacts resulting from accidents in oil drilling and other marine operations. Ice navigation and other offshore activities include risks for accidents which could lead to severe environmental damage of which the Exxon Valdez is a prominent example.

  The present clean-up techniques are useless, or not too efficient, against oil spilled to ice covered sea. By improving ice and weather information used for route selection in ice navigation, the risk for harming the vulnerable environment in these regions is reduced. Offshore activities in the Russian Arctic are growing and will require timely and accurate information about sea ice and

weather conditions in planning operations with minimum risk for accidents and harmful impacts on the environment.

- Coastal Zones: IRIS can contribute to Integrated Coastal Zone Management (ICZM) Demonstration Programme of DGXI, if the system is expanded to include various data from coastal zones. The programme is designed among other things to show how better information flow can lead to better use and management of coastal areas and their resources. This item is exactly where IRIS can contribute with solutions. Coastal zones are important for several aspects of the Community water policy (The Bathing Water Directive, The Urban Waste Water Treatment Directive) where meteorological and oceanographical data as provided by IRIS will be required in any management system.

Partners

N°	Organisation	Country
1	Helsinki University of Technology, HUT	Finland
2	Alfred Wegener Institute, Bremerhaven	Germany
3	Finnish Institute of Marine Research, Helsinki	Finland
4	Fortum Oil and Gas, Fortum	Finland
5	Technical Research Centre of Finland, VTT	Finland
6	Aker Finnyards Inc., Helsinki	Finland
7	Swedish Meteorological and Hydrological Institute, Västra Frölunda	Sweden
8	The Scottish Association of Marine Science, Oban, Argyll	UK
9	Wagenborg Shipping, Delfzijl	Netherlands

5. Research Infrastructures

ALOMAR eaRI – Arctic Lidar Observatory for Middle Atmospheric Research

RITA-CT-2003-506208

http://alomar.rocketrange.no/

Instrument:	FP6 Specific Support Action (Infrastructures)	Contract starting date: 01.01.2004
Total project cost:	2.501.808 €	Duration: 48 months
EC Contribution:	2.500.000 €	
Organization:	Andoya Rocket Range AS	Andenes, Norway
Co-ordinator:	Michael Gausa (michael@rocketrange.no)	
EC Contact person:	Anna Maria Johansson (anna-maria.johansson@ec.europa.eu)	

Abstract

Under the ALOMAR eARI ("enhanced" ARI) we offer the exceptional opportunity to investigate the physics, chemistry and dynamics of the Arctic atmospheric by access to a worldwide unique ensemble of sophisticated ground-based instruments (ALOMAR) and a new service of *in-situ* measurements through a rocket-launch "Hotel Payload" (HotPay).

Since 1998, ALOMAR gives funding for researchers using the facility under a Transnational Access contract. From 2000 to 2003 we enjoyed a significant increase in the number of applications to our infrastructure. Participants of 14 nationalities have applied. The number of participating countries, together with the permanent groups at ALOMAR, rises the unique opportunity for participants, especially for those from candidate states, to contribute to common research approaches (e.g. Global Change), which yields to a more coherent research and hence structures the ERA. ALOMAR is a part of the Andoya Rocket Range (ARR), a launch site for sounding rockets and a SME in the terms of 6th FP.

Numerous scientific projects take the advantage of the synergy created by the ALOMAR facility and the ARR, concurrently. Hence our services under the new ALOMAR eARI are enhanced. It includes the well-established access services from ALOMAR and the new opportunity to fly rocket-borne instruments. We offer two rocket-launches that can explore two different physical regimes, the middle atmosphere/lower ionosphere (50-120 km) and the auroral ionosphere (50-250 km). Each rocket can typically carry five to ten instruments measuring a variety of parameters. The rocket is the only platform that can bring scientific instruments into these height regimes. The ALOMAR eARI provides the launch vehicle, the operations, and the structure with a flexible service module including power and telemetry. The scientists contribute with their own instruments.

"Hotel Payload" (HotPay), ARR's latest innovation, is a very cost efficient way of bringing instruments into the middle atmosphere. Simplicity, standardisation and cost sharing ensure that the costs are significantly lower than for traditional sounding rocket programmes. HP is the crucial key to offer the launch services under the eARI.

For the majority of the European researches the ALOMAR eARI would be the only way participating in in-situ studies of this special height regime. Consequently the ALOMAR eARI will be a fascinating bottom up approach for new co-operations on the background of an expanding Europe.

Partners

N°	Organisation	Country
1	Andoya Rocket Range AS, Andenes	Norway

ARCFAC V – The European Centre for Arctic Environmental Research

026129

http://www.npolar.no/nvaa-lsf/

Instrument:	FP6 Transnational Access (Infrastructures)	Contract starting date: 01/03/2006
Total project cost:	1.850.412 €	Duration: 48 months
EC Contribution:	1.833.600 €	
Organization:	Norwegian Polar Institute	Norway
Co-ordinator:	Jon Børre ØRBÆK (jon.borre.orbaek@npolar.no)	
EC Contact person:	Anna Maria Johansson (anna-maria.johansson@ec.europa.eu)	

Summary

Located at the high latitude of 78°55' N, 11°56' E, the Ny-Ålesund International Research and Monitoring Facility is one of the world's northernmost human settlements, situated on Svalbard, Norway. This site represents an ideal permanent research platform in the European Arctic, with its mild climate, clean environment and easy accessibility by plane and boat. Together with the well-developed infrastructure with highly specialised research facilities established and used by a broad international research community, Ny-Ålesund strongly demonstrates its value as The European Centre for Arctic Environmental Research.

Six Research Platforms form the basis of this Research Infrastructure, together with the General Infrastructure providing accommodation and transportation as well as Logistical Services offered for field campaigns. The high latitude location and multidisciplinary research environment are ideal for research and monitoring within a broad range of contemporary Arctic Environmental Research with emphasis on: -Climate change and ecosystem response, -UV-radiation and biological effects, Long-range transported pollutants and ecotoxicology as well as many other disciplines.

The European Centre for Arctic Environmental Research form the northernmost (Arctic) baseline node within several climate research programmes and international networks. It is unique in Europe in light of the multitude of different environmental research and monitoring programmes running simultaneously at the same site, providing excellent conditions for multi- and interdisciplinary co-operation projects and data-exchange. As a modern research station in a clean natural laboratory, the European Centre for Arctic Environmental Research will continue to play an important role in Europe, providing access to a large number of scientists from an increasing number of countries taking part in Arctic research.

Partners

N°	Organisation	Country
1	Norwegian Polar Institute	Norway
2	Kings Bay Company	Norway
3	Norwegian Institute of Air Research	Norway
4	Alfred Wegener Institute for Polar and Marine Research	Germany
5	Institut Polaire français – Paul Emile Victor	France
6	Natural Environment Research Council, Swindon	UK
7	Norwegian Mapping Authority	Norway
8	Consiglio Nazionale delle Ricerche	Italy

ATANS – Enhanced Transnational Access to Abisko Scientific Research Station

RITA-CT-2004-506004

http://www.ans.kiruna.se/ans.htm

Instrument:	FP6 Specific Support Action (Infrastructures)	Contract starting date: 01/01/2005
Total project cost:	504.000 €	Duration: 48 months
EC Contribution:	504.000 €	
Organization:	The Royal Swedish Academy of Sciences	Stockholm, Sweden
Co-ordinator:	Terry Callaghan (terry.callaghan@ans.kiruna.se)	
EC Contact person:	Anna Maria Johansson (anna-maria.johansson@ec.europa.eu)	

Abstract

Abisko Scientific Research Station is located in one of Europe last remaining wilderness area. The station is operated year-round in a subarctic environment, it is well equipped with lab. - and field equipment for bio- and geoscientific investigations. The station can accommodate almost 100 scientists in comfortable rooms and apartments in immediate closeness to study areas. From the station a unique possibility to access a range of environments exist. Abisko is easily reached throughout the year by air, train, car or bus. The station was established in the beginning of the 20th century and has beside a unique scientific documentation in terms of more then 2500 publications also an existing long record of environmental data that give the users of the station an important background information on the environment surrounding the station. The station is internationally well known, and is visited by more then 500 visiting scientists yearly. The station will during the 4-year period be able to offer 4100 man-days for 140 scientists.

Partners

N°	Organisation	Country
1	Abisko Scientific Research Center, Abisko	Sweden

EISCAT_3D – European Next Generation Incoherent Scatter Radar

011920-DS

http://www.eiscat.se/

Instrument:	FP6 Design Study (Infrastructures)	Contract starting date: 01.05.2005
Total project cost:	2.945.383 €	Duration: 48 months
EC Contribution:	2.017.445 €	
Organization:	EISCAT Scientific Association	Kiruna, Sweden
Co-ordinator:	Gudmund WANNBERG (gudmund.wannberg@eiscat.se)	
EC Contact person:	Anna Maria Johansson (anna-maria.johansson@ec.europa.eu)	

Summary

The radars of the European Incoherent Scatter Scientific Association (EISCAT) are the World's leading ground based instruments providing high quality radar observations of the auroral and polar ionosphere and atmosphere. Current and future ionospheric and plasma physics research, geophysical environmental monitoring, modelling, and forecasting (e.g. for space weather, ionospheric corrections, and climate change) are driving requirements for both quasi-continuous observations and substantially improved spatial and temporal resolution.

A four year design study is proposed to investigate the technical feasibility, costs, and potential European manufacturers of a new next generation VHF incoherent scatter radar with distributed power amplifiers and an upgraded antenna array for both transmission and reception, together with at least two further, remote reception facilities, using phased arrays with multiple distributed receivers. The design study also encompasses essential developments in advanced signal processing, data collection, distribution, and analysis.

Partners

N°	Organisation	Country
1	EISCAT Scientific Association, Kiruna	Sweden
2	University of Tromsoe	Norway
3	University of Lulea	Sweden
4	Council for the Central Laboratory of the Research Councils, Didcot	UK

EISCAT_USERS_1 – Access to EISCAT facilities for new users

026077

http:/www/eiscat.se/

Instrument:	FP6 Transnational Access (Infrastructures)	Contract starting date: 01/01/2006
Total project cost:	580.213 €	Duration: 48 months
EC Contribution:	580.213 €	
Organization:	EISCAT Scientific Association	Kiruna, Sweden
Co-ordinator:	Anthony Paul VAN EYKEN (Tony.van.Eyken@eiscat.se)	
EC Contact person:	Anna Maria Johansson (anna-maria.johansson@ec.europa.eu)	

Summary

The EISCAT Scientific Association provides world-class research and training opportunities, in geophysics, signal processing, and high powered radar systems, which will be made available to a wider user community.

The Association owns and operates the World's leading incoherent scatter radars, and a powerful ionospheric modification facility. These systems are normally used for studies of the high latitude ionosphere and neutral atmosphere, but are also applicable to many other areas including studies of plasma physics, radio scattering processes, and the space environment.

This project will provide support for up to four new users annually to visit the EISCAT facilities, receive help and support to design suitable experimental schemes, up to 24 hours of radar observing time, and assistance with the subsequent data processing, analysis, and interpretation.

The EISCAT scientific and technical staff has extensive experience in providing this type of support to scientists from the existing Associate countries (Finland, France, Germany, Japan, Norway, Sweden, and the United Kingdom). The present project will extend the availability of the systems to scientists from other countries, particularly those from countries which have recently joined, or are seeking to join, the European Union.

The EISCAT radars represent a substantial investment in equipment and expertise in a unique European facility which is the world-leader in the field. Access to the systems can provide excellent introductions to state of the art experimental facilities, atmospheric and ionospheric physics, and advanced signal processing as well as to EISCAT's scientific research community.

The EISCAT Scientific Advisory Committee provides a competent review panel to evaluate, and to provide support for, experimental proposals from new users and user groups. A similar, smaller, and internally funded, programme has supported a number of users from non-EISCAT countries in recent years.

Partners

N°	Organisation	Country
1	EISCAT Scientific Association, Headquarters, Kiruna	Sweden

6. ERA-NET

EUROPOLAR - The European Polar Consortium: Strategic Coordination and Networking of European Polar RTD Programmes

517842

http://www.europolar.org/

Instrument:	FP6 Coordination action (CA/ERA-NET)	Contract starting date: 01/03/2005
Total project cost:	2.484.993 €	Duration: 48 months
EC Contribution:	2.484.993 €	
Organization:	Institut Polaire français Paul Emile Victor	Paris, France

Co-ordinator: Paul Egerton (europolar@esf.org)

EC Contact person: Ivan Conesa Alcolea (ivan.conesa-alcolea@ec.europa.eu)

Abstract

EUROPOLAR ERA-NET is a consortium of 25 Ministries, Funding Agencies and National Polar RTD Authorities from 19 European countries and of the ESF/European Polar Board. With a combined critical mass of over 500 Million Euros per annum, it is the most significant initiative to coordinate European Polar RTD Programmes ever attempted. EUROPOLAR ERA-NET will exert a massive and positive impact on this domain and lead to long-term durable partnerships within Europe and internationally. EUROPOLAR ERA-NET will also encourage and support the closer relationship of National Polar RTD Programme managers in Europe fostering cooperation and leading to joint Programme activities. EUROPOLAR ERANET will also deepen and strengthen the interactions between countries with large Polar RTD Programmes and nations with evolving Polar Programmes in central and south-eastern Europe, encouraging exchange of experiences and best practice on management and financing of Programmes and infrastructures. The presence of key European and international organizations within EUROPOLAR ERA-NET will open up a vast network of human and material capital. The structuring and coordination of European Trans-national elements will enable the construction of mechanisms to mobilize joint funding flows and the reciprocal access to research Infrastructures. The long-term goal of the European Polar Consortium is the development of a 'European Polar Entity' that will be established through dialogue at a political level beyond the EUROPOLAR ERA-NET and will enable Europe to maximize and direct its critical mass at the global level.

Partners

N°	Organisation	Country
1	Institut Polaire français Paul Emile Victor	France
2	European Science Foundation, Strasbourg	France
3	Fonds zur Förderung der wissenschaftlichen Forschung	Austria
4	Fonds National de la Recherche Scientifique	Belgium
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